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Development and Findings From the Spot and Runway Departure Advisor (SARDA) Human-in-the-Loop (HITL) Simulation Experiment

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

NOMENCLATURE

2-D	Two dimensional
3-D	Three dimensional
4-D	Four dimensional
A-SMGCS	Advanced Surface Movement Guidance and Control System
AAL	American Airlines
ADR	Airport Departure Rate
AMA	Airport Movement Area
ANOVA	Analysis of Variance
ARMD	Aeronautics Research Mission Directorate
ARTCC	Air Route Traffic Control Center
ASP	Airspace Systems Program
ATC	Air Traffic Control
ATCT	Air Traffic Control Towers
ATG	Airspace Traffic Generator
ATM	Air Traffic Management
ATMTE	Air Traffic Message Translation Engine
CAAT	Collision Avoidance for Airport Traffic
CASM	Collaborative Airspace Surface Metering
CD&R	Conflict Detection and Resolution
CDM	Collaborative Decision Making
CDQM	Collaborative Departure Queue Management
CFR	Call For Release
CM	Communications Manager
CMUI	Communications Manager User Interface
COGINE	Computational Engine
ConOps	Concept of Operations
CPDLC	Controller Pilot Data Link Communication
CPU	Central Processing Unit
CTD	Concepts and Technology Development
DFW	Dallas/Fort Worth International Airport
DISSEMINATE	Distributed Surface Management Governance Model
DLR	German Aerospace Center
DMAN	Departure Manager

DP	Dynamic Programming
DRB	Departure Runway Balancer
DS	Departure Scheduler
DST	Decision Support Tool
EDCT	Expect Departure Clearance Time
EFS	Electronic Flight Strips
EGF	Eagle Flight
EMMA2	European airport Movement Management by A-SMGCS, Part 2
ETA	Estimated Time of Arrival
FAA	Federal Aviation Administration
FCFS	First Come, First Served
FD	Flight Deck
FFC	FutureFlight Central
GC	Ground Controller
GDP	Ground Delay Program
GM	Ground Manager
GPS	Ground Pilot Station
GS	Ground Stop
GUI	Graphical User Interface
HITL	Human-in-the-Loop
ID	Identification
IFR	Instrument Flight Rules
IIFD	Integrated Intelligent Flight Deck
JPDO	Joint Planning and Development Office
LC	Local Controller
LP	Linear Program
MARS	Mission Awareness Rating Scale
McTMA	Multi-Center Traffic Management Advisor
MILP	Mixed Integer Linear Program
MIT	Miles-In-Trail

MPEG	Moving Pictures Expert Group
NAS	National Airspace System
NASA	National Aeronautics and Space Administration
NextGen	Next Generation Air Transportation System
nm	nautical miles
NRA	NASA Research Announcement
PB	Push Back
PBC	Push-Back Calculator
PDRC	Precision Departure Release Capability
PP	Pseudo-Pilot
RFA	Research Focus Area
RNAV	Area Navigation
RS	Runway Scheduler
RTA	Required Time of Arrival
SA	Separation Assurance; Situation Awareness
SAGAT	Situation Awareness Global Assessment Technique
SARDA	Spot and Runway Departure Advisor
SBIR	Small Business Innovative Research
SDO	Super Density Operations
SDSS	Surface Decision Support System
SESAR	Single European Sky ATM Research Program
SESO	Safe and Efficient Surface Operations
SFO	San Francisco International Airport
SME	Subject Matter Expert
SMS	Surface Management System
SODAA	Surface Operations Data Analysis and Adaptation
SOSS	Surface Operations Simulator and Scheduler
SRP	Spot Release Planner
SRP-LT	Spot Release Planner—Long Term
SRP-RS	Spot Release Planner—Runway Scheduler
SRP-ST	Spot Release Planner—Short Term
SWIM	System Wide Information Management

TAPSS	Terminal Area Precision Scheduling System
TCP/IP	Transmission Control Protocol/Internet Protocol
TLX	Task Load Index
TMA	Traffic Management Advisor
TMI	Traffic Management Initiative
TMU	Traffic Management Unit
TOBT	Target Off-Block Time
TOD	Taxiway Optimizer and Deconfliction
TRACON	Terminal Radar Approach Control
TS	Taxi Scheduler

DEVELOPMENT AND FINDINGS FROM THE SPOT AND RUNWAY DEPARTURE ADVISOR (SARDA) HUMAN-IN-THE-LOOP (HITL) SIMULATION EXPERIMENT

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SUMMARY

Airports are often a capacity-limiting constraint for the rest of the National Airspace System (NAS). This report describes a recent effort to investigate methods to improve surface operations by creating support tools for ground and local controllers working at Air Traffic Control Towers (ATCT). The set of tools developed is collectively known as the Spot and Runway Departure Advisor (SARDA). The SARDA research activity addresses airport surface congestion problems under the Safe and Efficient Surface Operations (SESO) research focus area within the Airspace Systems Program. SARDA research is specifically being performed at NASA Ames Research Center.

The goal of SARDA is to develop a tower controller advisory tool for the efficient flow of surface traffic. Creating such a tool and validating its effectiveness entails developing optimized scheduling algorithms, creating the advisories and human computer interfaces for the ground and local controllers, designing and building a high-fidelity, real-time human-in-the-loop (HITL) simulation facility to evaluate the effectiveness of the advisories, and conducting simulation studies to validate the use of the advisories in a realistic simulation environment.

In today's operations, the ground controller clears the aircraft from a spot as soon as possible by directing it onto a taxiway. The spot denotes a physical location where aircraft are handed off between ramp and ground controllers (outbound) and ground to ramp controllers (inbound). Ground controllers then hand off the aircraft to local control. The local controller then clears the aircraft from the taxiway to a departure queue. Each aircraft moves forward in its queue until it receives a takeoff clearance. During busy periods, the runway queues and taxiways become congested, and aircraft are subjected to stop-and-go operations. The proposed concept of operations (ConOps) for the midterm system (2015–2018) would impose some delays at the spots in busy traffic periods in order to reduce taxiway and runway queue delays, particularly the number of stop-and-go operations. Optimization algorithms for surface planning have been developed that will form the basis of decision support tools for the ground and local controller to achieve more efficient operations during busy traffic periods.

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The core scheduling algorithms being developed for SARDA for the midterm are the Spot Release Planner (SRP) and the Runway Scheduler (RS). Each scheduler is formulated as a deterministic optimization problem with different objective problems and decision variables. SRP provides the optimum sequence of spot release and approximate release times as output. Essentially, it provides a mechanism for delaying the aircraft at the spot, rather than at departure queues, resulting in less congested surface traffic without sacrificing runway throughput. The RS manages the operations of a single departure runway, scheduling takeoffs as well as runway crossings for arrival aircraft. The scheduler must satisfy constraints such as wake separation criteria, miles-in-trail (MIT) restrictions, and the Expect Departure Clearance Time (EDCT).

SRP and RS introduce a concept and an implementation approach to providing time-based metering on the surface. SRP provides release-time metering advisories for all control points, which are the spots, to the ground controller. RS provides the local controller with two metering locations: the runway departure point and the active runway crossing intersections. Taken together, SRP and RS begin to provide metering advisories on the airport surface for both departures and arrivals. This represents the first attempt at an integrated approach to provide airport-wide improvement in traffic management and hence, efficiency.

This sequence and schedule data as generated by SRP and RS need to be displayed in an effective manner to the ground and local controllers so that the quality of the planning information can be evaluated in simulation. An initial simulation was conducted to examine the operator interface. Future evaluations will use these findings to develop candidate decision support tools (DSTs), which can be further evaluated in FAA facilities. Two display options were investigated: a datatag advisory format and a timeline advisory format. The datatag format incorporated the advisory information into the datatag element of each relevant aircraft on the plan-view map displays. The timeline version presented visualization of temporal information in a separate window on the workstation adjacent to the map displays. These display options were compared with a baseline mode in which no advisory information was provided to the controller.

In order to provide a sufficiently realistic environment for a controller evaluation of these tools, a major airport, Dallas/Fort Worth International Airport (DFW), was selected for a simulation evaluation. A real-time HITL simulation evaluation of DFW was conducted in April 2010. Because the primary purpose of the evaluation was to demonstrate the proof-of-concept of the proposed surface concept and algorithms, an out-the-window visual format was not used. In addition, the simulation was restricted to the operations on the east side of DFW, in order to keep the number of participants (controller and pseudo-pilots (PPs)) at a manageable level. The two controller subjects, who alternated at the ground and local controller positions, were retired Federal Aviation Administration (FAA) controllers from DFW. The pseudo-pilots had experience as commercial or private pilots, or former air traffic controllers.

The April 2010 Simulation consisted of 56 simulation runs, each lasting 45 minutes. In addition to the display variable (timeline, datatag, or baseline) described above, traffic rate was the other key variable; traffic rates were either based on current DFW loads or two heavy rates, both of which represented an increase of 50 percent over today's operation. Both qualitative and quantitative data were collected, and key results are highlighted below.

Data collected during the simulation indicate, for departure traffic, a consistent reduction in the average number of stops, from about six stops to three, in heavy traffic when the SRP advisories were used. This was not accomplished at the expense of adding stops for arriving traffic because the data indicate the same average number of stops for arrivals across all test conditions.

Reducing the number of stops also impacted the average total departure fuel consumption, which was reduced 45 percent with the use of SARDA.

Controllers indicated a preference for the timeline display format compared to the datatag representation. According to self-reports from questionnaires, controllers indicated that the timeline made it easier to plan ahead and kept clutter off the map. They also indicated information updates and sequence changes could be recognized more easily with the timeline display format.

Controllers had difficulty adapting to the spot release times because the sequences recommended by SRP were often inconsistent with current practices. In addition, SRP sequence and release time update rate of 40 seconds were disruptive to their planning model.

Analyses indicated that the high traffic condition increased perceived workload for ground controllers and local controllers. However, analyses also indicated little impact of SARDA advisories on participants' perceived workload.

Ground controllers showed decreased situation awareness when using the SRP advisories. This finding is consistent with controllers' subjective reports that they found the SRP advisories disruptive to planning, which is critical to developing and maintaining situation awareness.

Results generally indicate significant promise for SARDA. Future studies are planned that will modify the SARDA display as per controller evaluations, improve the robustness of the algorithms and add uncertainties to the evaluations, and consider the impact of a realistic tower environment, with controller attention split between monitoring displays and observing traffic by looking out the window. These will be evaluated in follow-on real-time HITL simulations and eventually at an FAA field site.

To date, the primary focus of the SARDA research involves building a proof-of-concept for implementing metering of ground traffic. The operational concept involves pushing delays from the departure queue back into the spot and ramp area. However, this concept also imposes ramp management congestion and will require complimentary tools to aid ramp controllers. This ramp control research will commence after maturation of the SARDA scheduling technology and ideally in partnership with an air carrier.

INTRODUCTION

The Spot and Runway Departure Advisor (SARDA) work represents a key airport surface management activity within the Safe and Efficient Surface Operations (SESO) research focus area. The goal of the SARDA research is to develop a controller advisory tool for increasing the environmental and operational efficiency of surface traffic. Creating such a tool and validating its effectiveness entails developing optimized scheduling algorithms; creating advisories and human computer interfaces to interact with ground and local controllers; designing and building a high-fidelity, real-time human-in-the-loop (HITL) simulator to evaluate the effectiveness of the advisories; and conducting simulation studies to validate advisory usage in a realistic (heavily congested, major airport) environment.

This report provides the background on the SESO project, and describes the SARDA concept and tool and how it relates to other ongoing Next Generation Air Transportation System (NextGen) research. The report then discusses the operational concept, provides an overview of the schedulers and the human factors evaluation approach, describes the simulator, and presents the simulation results and findings. The appendices include a detailed description of the real-time high-fidelity HITL surface simulator, controller and pseudo-pilot training materials, and scenario development.

SESO is one of five Research Focus Areas (RFAs) in the NextGen Air Traffic Management (ATM) Concepts and Technology Development (CTD) project under NASA's Aeronautics Research Mission Directorate (ARMD) Airspace Systems Program (ASP) (ref. 1).

SESO research is investigating new technologies and concepts to increase airport capacity by enhancing the flexibility and efficiency of surface operations. The research will result in evaluations of integrated automation technologies and procedures designed to:

- Improve surface traffic planning through: 1) balanced runway usage; 2) optimized taxi planning of departures and arrivals; 3) departure scheduling satisfying environmental constraints, dynamic wake vortex separation criteria, and constraints driven by other NAS domains; and 4) balanced runway usage and efficient runway configuration management through coordination with Super Density Operations (SDO).
- Provide trajectory-based surface operations capabilities by: 1) modeling aircraft surface trajectory prediction and synthesis, 2) developing pilot display requirements and technologies for four-dimensional (4-D) taxi clearance compliance, and 3) developing taxi clearance conformance monitoring algorithms and procedures.
- Maintain safe ground operations through the development of conflict detection and resolution (CD&R) concepts for both airborne and ground-based systems. The SARDA research is part of the “improved surface traffic planning” thread, which is the primary focus of this document.

Both in-house researchers and external research partners (through the NASA Research Announcement (NRA) and Small Business Innovative Research (SBIR) contracting vehicles) are performing surface research. NRAs have been awarded to academic institutions, nonprofit organizations, and industry to perform foundational research to address technology gaps. The NASA

SBIR program provided an opportunity for small, high-technology companies and research institutions to participate in NASA-sponsored research and development efforts in key technology areas. Table 1 identifies the research partners that have contributed to the SESO research.

TABLE 1: SESO RESEARCH PARTNERS

Topic	NRA	SBIR
Surface Optimization Under the Presence of Uncertainties	Team 1. San Jose State University Team 2. Georgia Institute of Technology	
Modeling Environmental Factors in Surface and Terminal Optimization	Metron Aviation	
Surface Trajectory Modeling and Conformance Monitoring	Mosaic ATM	
Surface Conflict Detection and Resolution	Team 1: Optimal Synthesis, Inc. Team 2: Sensis Corporation	
Trajectory Design to Benefit Trajectory-Based Surface Operations		Optimal Synthesis, Inc.
Off-Nominal Airport Traffic Management		Mosaic ATM
ATC Operations Analysis Via Automatic Recognition of Clearances		Mosaic ATM

BACKGROUND

Airports are one of the most important resources in the air transportation system. In many situations, however, airports are a limiting constraint for the rest of the airspace system, adversely affecting both throughput and efficiency of the entire National Airspace System (NAS) (refs. 2,3). Many contributing factors conspire to make airports the bottleneck in the NAS. Notionally, those limiting factors can be divided into two categories: physical and operational.

An example of a physical limiting factor is poor visibility due to fog, which routinely enshrouds San Francisco International Airport (SFO) during the summer months. This reduces the airport arrival rate, potentially reducing the airport's capacity to half of a clear-day operation. A closing of an active runway causes a similar reduction in airport capacity. One example of an operationally limiting factor occurs when a departure aircraft has to wait at the front of the departure queue to meet its miles-in-trail (MIT) restriction over a particular departure fix. In a single-queue configuration, the aircraft can block other aircraft in the queue from advancing. In another example, an aircraft that is assigned an Expect Departure Clearance Time (EDCT) arrives at the front of the queue early but has to wait until the appropriate release window approaches. These sample conditions can impose undue inefficiency in the traffic management workflow. The consequences of operational limiting factors can be as serious as physical factors in terms of operational costs to airlines and environmental impacts.

These two types of factors combine to make surface management and airport operations less efficient, and while they do happen on a frequent basis, they are usually managed adequately by current-day procedures and staffing levels. However, with the anticipated increase in traffic demand in the future, current human skill sets and staffing levels may limit efficiency. Therefore, new decision support tools (DSTs) and capabilities will be required to assist tower Air Traffic Control (ATC) personnel to smoothly and effectively manage the anticipated growth in traffic.

The airport efficiency characteristics can be defined using various types of metrics, such as: increase in airport throughput, increase in runway usage, reduction in delay, reduction in taxi time, reduction in fuel burn and emissions, and reduction in arrival gate conflict and gate holding. The examples also illustrate potential areas of research to increase airport efficiency and alleviate surface congestion. It may be that each factor contributes an incremental change in system efficiency, but taken as a whole, they can significantly increase overall airport efficiency, affecting arrivals and departures as well as surface traffic management.

The airport bottleneck problem is a worldwide phenomenon, happening at all major airports around the world, and it has caught the attention of the global research community. Recently, research organizations both in the United States and Europe have been focusing on the issues of inefficient airport surface operations and trying to develop new concepts and procedures, as well as supporting technologies to improve the capacity of the airport system. The runway system has been identified as a key constraint (ref. 4), and it has been shown that departure analysis could lead to the identification of control points where the runway operations can be affected. A conceptual design of a departure planner has been developed, composed of functional components based on a queuing model approach (ref. 5), with each component providing an automation aid to optimize the operation corresponding to the control point (e.g., gate, ramp). In addition, researchers are investigating concepts to alleviate these airport congestion problems such as synthesizing precise runway crossing times (ref. 6), and providing safe and efficient taxi timing in collaboration with the flight deck (ref. 7). Various surface optimization concepts and techniques were also researched using fast-time simulations (refs. 8,9).

A queuing model of surface operations at Boston Logan International Airport has also been developed, and delay reduction via a gate holding control scheme was evaluated (ref. 10). More recently, a framework of coordinated surface operations among gate, ramp, taxiway, and runways was developed (ref. 11); an optimization algorithm to schedule individual aircraft taxiing on a network of nodes and links was part of this framework. A comprehensive optimized taxi scheduler has also been developed (ref. 12) and was later improved by adding detailed physical and operational constraints (ref. 13). Taxi delay reductions compared to a taxi schedule based on the first-come, first-served (FCFS) method were then demonstrated.

In addition, efficient runway scheduler algorithms have also been developed with the objective of maximizing the throughput of runway operations while satisfying various constraints (refs. 14,15).

Issues of fuel consumption and resulting environmental impacts due to inefficient surface operations have gained more attention in recent years. A comprehensive analysis of fuel consumption and emissions during aircraft taxi operations at Dallas/Fort Worth International Airport (DFW) has been conducted (ref. 16). In the analysis, stops (in both taxiways and runway queue) and resulting acceleration events constitute approximately 18 percent of total fuel spent in surface operations. In other words, at least the same amount of fuel can be saved if ‘stop-and-go’ situations of aircraft on taxiways and runway queues can be eliminated.

In an attempt to evaluate new concepts and early technologies in the field, the Federal Aviation Administration (FAA) evaluated the DST developed based on the concept of the Collaborative Departure Queue Management (CDQM) at Memphis International Airport (ref. 17). The objective of the tool is to deliver a strategic surface traffic plan that is relatively easy for the tower controller to execute without significant changes in operational procedures.

In Europe, the German Aerospace Center (DLR) conducted a field evaluation of the European airport Movement Management by an A-SMGCS, Part 2 (EMMA2) (ref. 18), a prototype surface DST, at Prague Airport in 2008. In the test, the Departure Manager (DMAN) component provides both ATC and airlines with a target off-block time (TOBT) of individual departure aircraft to meet the operational criteria.

Both CDQM and EMMA2 tools use Electronic Flight Strips (EFS) as a means for communication between the tower controllers and the decision support system. EMMA2 requires a data link capability via a Controller Pilot Data Link Communication (CPDLC) to send both taxi route and runway time information. These experiments are important first steps towards the trajectory-based surface operations envisioned both by the Next Generation Air Transportation System (NextGen) (ref. 19) and the Single European Sky ATM Research Program (SESAR) (ref. 20), where the trajectories of aircraft are planned and controlled with the aid of automation assistance.

However, in these studies there is a gap in optimally addressing the access to the taxiway system itself through spots or gates. Furthermore, system robustness and computational costs during implementation have not been adequately addressed. The current SARDA research seeks to provide ground and local controllers with a concept and implementation approach to provide optimal time-based metering on the airport surface. The SARDA scheduler will provide release-time metering advisories at all control points, which include the spot for the ground controller, and the runway departure point and active runway crossing intersections for the local controller. Essentially, it provides a mechanism for delaying the aircraft at the spot, rather than at departure queues, resulting in less congested surface traffic without sacrificing runway throughput. The scheduler provides metering advisories for both arrivals and departures.

This document presents the development, implementation, and testing of a "midterm" concept of optimized airport surface operations developed as part of NASA's surface optimization research, with midterm implying targeted usage beginning around 2015–2018. Designs of the system architecture and individual components to realize the developed concept are presented. Further, based on this concept, a prototype DST is described; the tool could be used by the air traffic control tower (ATCT) controllers to improve efficiency of airport surface operations, as well as to reduce environmental impacts. Results of the real-time, human-in-the-loop (HITL) simulation for testing the tool and validating the concept are also presented.

The Spot and Runway Departure Advisor (SARDA) Research

The Spot and Runway Departure Advisor (SARDA) project was initiated in July 2009 under the direction of the SESO research focus area. The goals of the effort are to develop a concept of operations for a midterm ATCT DST to enable efficient operations, build a HITL surface simulation capability for ATCT controllers, and conduct initial experiments to evaluate performance of the surface optimization algorithms as well as the usability of the tower controller tool. The assembled team put forth a technical strategy and created an experimental plan to test the proof-of-concept. The researchers developed two surface optimization algorithms, the Spot Release Planner (SRP) and the Runway Scheduler (RS).

The team's activity was divided into four areas: Concept of Operations (ConOps)/algorithm development, software development, evaluation and testing, and human factors. A high-level outline of the tasks in each area is listed.

- ***ConOps/algorithm development***
  - Develop a ConOps for a surface traffic management tool for ground and local controllers at a busy airport.
  - Develop and test scheduling algorithms to generate optimal advisories for departures waiting at the spots and runway departure queues.
  - Develop requirements for the human-computer user interface with the schedulers.

- ***Software development***
  - Develop software architecture to support scheduling and user interface modules.
  - Integrate (plug-in) modules within the Surface Management System (SMS) framework.
  - Integrate the Airspace Traffic Generator (ATG) and SMS systems.
  - Develop and implement the user interfaces designed by the human factors researchers.
- ***Testing and evaluation***
  - Develop traffic scenarios and data collection test matrix.
  - Perform system integration and testing.
  - Develop training materials and conduct training of pseudo-pilots.
  - Conduct simulation tests.
  - Perform data recording and archival of simulation runs, traffic scenario, voice communication, and video capture.
  - Analyze scheduling performance.
- ***Human factors***
  - Develop the human-computer interface and graphical user display.
  - Develop controller classroom training material.
  - Develop questionnaires for test subjects (e.g., controllers) and pseudo-pilots.
  - Participate as active observers during test runs and administer questionnaires after each test.
  - Conducted post-run interviews of controllers.
  - Analyze human factors data.

DFW was modeled for the purposes of conducting simulation experiments. While the entire airport was modeled, all west-side operations were controlled by automation. Our test subjects, retired DFW tower controllers and supervisors, controlled traffic on the east side of DFW.

Testing of the SARDA technology occurred in three stages, with each stage phasing in a greater level of fidelity. The first shakedown simulation was conducted at the FutureFlight Central (FFC) facility at Ames Research Center in December 2009 for 5 days, including 2 days of training. The Spot Release Planner (SRP), a ground controller tool that provides optimal sequence and timing for releasing aircraft from the spot, was implemented and tested, but traffic was simulated for only one DFW terminal (Terminal A).

In March 2010, the second shakedown simulation was conducted for 5 days with an extended scope that included traffic to all east-side terminals (A, C, and E). In addition to the SRP, the Runway Scheduler (RS) was introduced and tested during this phase. The RS generated an optimal sequence of runway operations (i.e., both takeoffs and runway crossings) for the local controller.

Lastly, a data collection simulation was conducted in April 2010 with the same set of configurations as the March simulation, but with modified test scenarios and control procedures. The simulation lasted for 2 weeks. A detailed description of the supporting materials from the April simulation is presented in Appendix G.

The objectives of the SARDA research (which address the first SESO research objective, as presented in the *Introduction* section) are as follows:

- Implement midterm ConOps of a tower controller tool using the SRP and RS.
- Evaluate performance of the integrated system of SRP and RS.
- Develop test procedures for evaluation of the algorithm and its benefits.
- Conduct preliminary human performance and workload evaluations.
- Continue development of the real-time HITL simulation platform to support future surface research objectives.

NOTE: In NASA parlance, midterm represents the 2015–2020 time frame. The FAA's implementation and deployment time frame will occur later, due to further system development and hardening for operational deployment.

Relationship With Other Safe and Efficient Surface Operations (SESO) Research

The SARDA research has the potential to extend and integrate with other research areas that are being investigated under the SESO project. The list below highlights potential integration research.

1. Integrated Surface Management With Flight Deck (FD). Extending the SARDA capability to integrate with flight deck (FD) automation tools can assist pilots in complying with taxi clearances. This will require the SARDA tool to integrate with FD technology to assist pilots in meeting the Required Time of Arrival (RTA) at the end of the taxi route (i.e., runway threshold or runway queue entry point). For example, in the absence of datalink between FD and tower, a single RTA for the end of taxi route can be issued to the pilot by the controller via voice communication. The pilot could manually enter at most one RTA in the FD automation tool. With datalink, there is a possibility of automatically relaying multiple RTAs to the FD automation.

2. Taxi Conformance Monitoring. The SESO project was awarded research through a NASA Research Announcement (NRA) to develop a concept and algorithms for the taxi conformance monitoring function. The taxi conformance monitoring function includes three categories of conformance monitoring:

- Spatial route conformance check.
- RTA conformance monitoring function.
- RTA conformance prediction function.

The taxi conformance monitoring function is required for trajectory-based surface operations, where the conformance monitoring function enables the surface traffic scheduler function to provide revised RTAs if aircraft are not conforming to the given RTAs. In particular, a portion of the conformance monitoring function can be integrated with the SARDA tool, such that predefined nonconformance situations can trigger the scheduling function to recalculate the spot release schedule of departure aircraft. In addition, the route conformance checking function can trigger the function that generates an alert for tower controllers when an aircraft enters into a wrong taxiway.

3. Surface Conflict Detection and Resolution (CD&R). The surface CD&R research under the SESO project includes both aircraft- and ground-based functions. The objectives of aircraft-based CD&R research are to:

- Develop concept and requirements for CD&R in the terminal maneuvering area for current and emerging NextGen operations.
- Develop and evaluate CD&R algorithms through fast-time simulations.
- Evaluate conflict alert display concepts and alert timing through HITL simulations.
- Expand algorithms to enable accurate CD&R for emerging NextGen operations.

Langley Research Center has developed a concept and requirements known as Collision Avoidance for Airport Traffic (CAAT). The concept usability evaluation was conducted in April 2009, and piloted simulations to evaluate CAAT algorithms were conducted in October 2009 at Langley Research Center (ref. 21).

In 2010, the SESO research focus area began research on ground-based CD&R functions through the NRA research teams (table 1). The objectives of the ground-based CD&R research are to:

- Formulate ConOps for ground-based CD&R framework.
- Develop performance models of surveillance systems.
- Develop a rule-based framework for short-term conflict detection.
- Develop probabilistic trajectory-prediction-based framework for long-term conflict detection.
- Develop search-based short-term conflict resolution algorithm and long-term conflict resolution procedure.
- Implement CD&R algorithms, and integrate and test with surface traffic simulation.

The purpose of surface CD&R is to ensure the safety of surface operations by providing mechanisms to detect conflicts and provide an alert to pilots of the aircraft involved in the conflict situation. The short-term conflict detection function detects conflicts due to loss of separation between aircraft in a very near future (e.g., less than 30 seconds) or entering into a protected area such as an active runway occupied by another aircraft. The long-term conflict detection, on the other hand, detects any conflicts due to nonconformance of the aircraft taxi schedule, which may not necessarily cause an immediate safety risk but may cause strategic conflicts. Both short- and long-term CD&R functions are critical components for the NextGen surface operations. There is a potential for integration of surface CD&R function with the surface DST, such as the SARDA tool, in conjunction with surface scheduling and taxi conformance monitoring.

Relationship With Other Concepts and Technology Development (CTD) Research

The SARDA tool has great potential to integrate with DSTs being investigated outside the SESO research. For example, the Precision Departure Release Capability (PDRC) being developed by NASA researchers is a candidate for such integration (ref. 22). PDRC provides automated communication between tower ATC and the en route traffic manager, and uses trajectory-based OFF (takeoff) time prediction for en route departure scheduling in Call For Release (CFR) situations. Notionally, PDRC will have better prediction of OFF times because by using the SARDA advisories, controllers can provide a more consistent departure time with less uncertainty.

The Terminal Area Precision Scheduling System (TAPSS) concept is being investigated within the Super Density Operations (SDO) research team. The TAPSS tool provides a precision scheduling algorithm and controller advisory for arrival aircraft in the terminal airspace. Terminal operations with assistance from such a precision scheduling tool will contribute to improved prediction of arrival times of aircraft landing on the airport. The SARDA tool will benefit from integration with the terminal DST in developing the surface taxi schedule (ref. 23).

The SARDA tool also needs to receive relevant traffic information from both terminal and en route ATC. Departure fix closure, and Traffic Management Initiatives (TMIs) such as miles-in-trail (MIT) restrictions and Expect Departure Clearance Time (EDCT) are among the needed information. The scheduling algorithms within the SARDA tool need such information in computing an optimal schedule for departure aircraft.

Technology Integration

As presented thus far, various research groups (in-house, NRA, and SBIR) are tackling the different aspects of the surface problem. They all help contribute to the goals set forth by the SESO project. An initial goal was for NASA to ease the integration of disparate pieces of research into one coherent platform and technology. NASA selected the Surface Management System (SMS) (ref. 24) to conduct the SARDA research leveraging the prior development of SMS. The SMS technology has been transferred to the FAA and was renamed the Surface Decision Support System (SDSS). SDSS and NASA's SMS share practically the same codebase, using some software management branching scheme to allow and reflect the unique requirements of each organization.

During the SARDA development, the SMS software was re-architected to provide a plug-in architecture. The use of the modular plug-ins allows NASA researchers the freedom to develop new technologies without impact to the FAA's operational code. Additionally, NASA hopes to transfer the functionally discrete and modular software pieces to the FAA as each piece matures independently. The SARDA team intends to capitalize on the modularity by recommending that the NRA teams deliver their technologies using the modular SMS plug-in format. NASA will integrate, test, validate, and if applicable, incorporate the new technologies into the SMS baseline.

The Human Factors Element

This document contains a human factors section, which is focused on the tool's impact (workload and situation awareness) on the controllers. More information is presented in the following sections: *Human Factors Investigation, Results and Findings, Human-in-the-Loop Lessons Learned and Limitations, Appendix C: Controller Training Material,* and *Appendix H: Human Factors Questionnaires.*

SARDA CONCEPT OF OPERATIONS (CONOPS)

In today's operations, the ground controller clears the aircraft from a spot as soon as possible by directing it onto a taxiway. The spot denotes a physical location where ramp control makes the handoff to ground control. Ground then hands off the aircraft to local control. The local controller then clears the aircraft from the taxiway to a departure queue. Each aircraft then moves forward in its queue until it receives a takeoff clearance. During busy periods, the runway queues and taxiways become congested, and aircraft are subjected to stop-and-go operations.

The proposed SARDA ConOps for the midterm system will impose some delays at the spots in busy periods in order to reduce taxiway and runway queue delays, particularly stop-and-go operations. Put another way, the concept of time-based metering will be introduced to the surface domain. Metering will occur at two locations: metering out of the spot into the active movement area and metering departures at the departure queues.

The airport surface domain of interest covers the area where departure and arrival aircraft operate, including ramps, taxiways, and runways. Figure 1 illustrates a generic airport surface layout. Optimization algorithms for surface planning have been developed to aide ground and local controllers by providing efficient operations during busy periods. Table 2 lists the tower controllers, their functions, and the corresponding scheduling support tool.

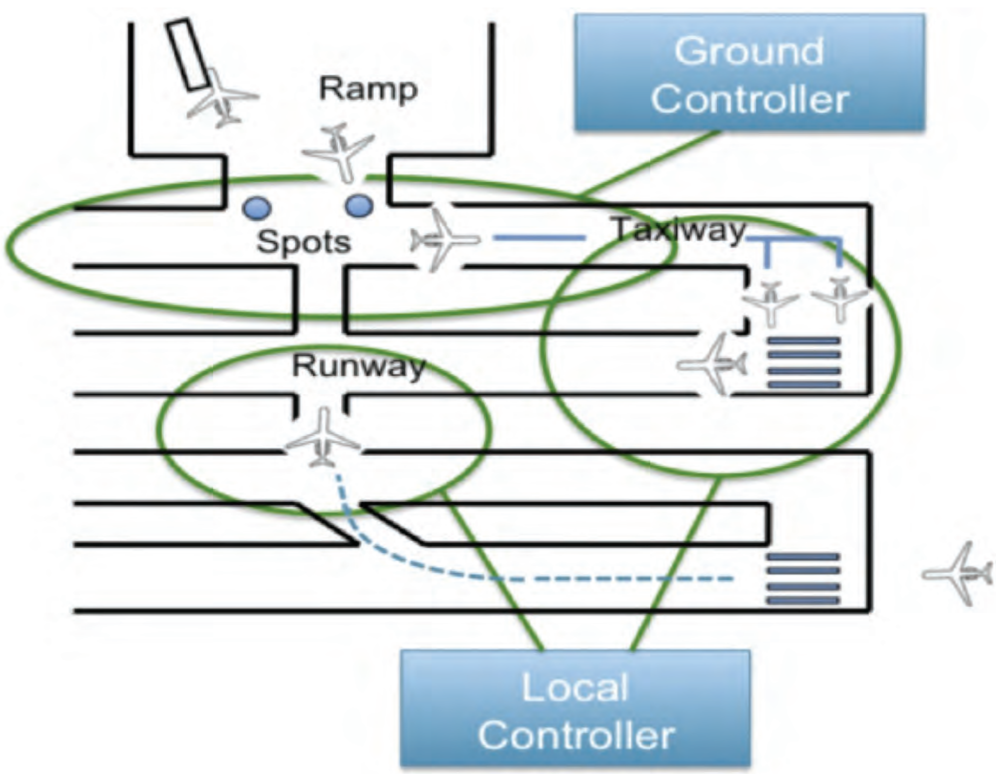

Figure 1: Generic airport surface layout.

TABLE 2: CONTROL DECISION AND DECISION SUPPORT FUNCTION FOR TOWER CONTROLLERS

Controller Position	Control Decision	Decision Support Function	Tools (Scheduling)
Ground	Release aircraft to taxiway	Sequence and timing advisory	Spot Release Planner (SRP)
Local	Runway operation for takeoffs and runway crossings	Takeoff and runway crossing sequence advisory	Runway Scheduler (RS)

The operations in the ramp area include passenger deplaning/boarding, refueling, food catering services, loading/unloading passenger luggage, etc. Ramp controllers control the pushback of aircraft from the gate when the aircraft are ready for departure. Ramp control may fall under the jurisdiction of the airlines, airport authority, or the FAA. However, the ground and local controllers working in an Air Traffic Control Tower (ATCT) strictly control aircraft movement on taxiways and runways. When an aircraft reaches the spot (the handoff point between the ramp area and the taxiway system, typically marked on the pavement with a number), the ground controller provides taxi instruction to the pilot and clears the aircraft to taxi into the movement area.

The ground controller maneuvers traffic on the surface and delivers departure aircraft to the assigned runways safely and efficiently, and vice versa for arrival aircraft. The responsibility of a local controller is to manage runway operations, including takeoff, landing, and runway crossing. Typically, there is a queue or multiple queue lanes of departure aircraft formed near the runway (at the departure queue), and the local controller determines sequence of takeoff (e.g., first come, first served), and clears aircraft for takeoff based on the rules of wake separation and other separation criteria. The entire sequence of departure runway operations mentioned above involves the following decision factors from the perspective of the tower controller:

- Time to enter the taxiway from the spot.
- Taxi route, along with separation among aircraft on the taxiway and prioritization at intersections.
- Queue area management (a queue area can have more than one lane (fig. 1)). In this case, assignment of aircraft to an appropriate queue lane needs to be decided.
- Time for takeoff; clearance times should consider wake separation, Area Navigation (RNAV) procedures, departure fix rate, runway crossing of arrival flights, and other factors.
- Time for active runway crossing.
- Application of Traffic Management Initiatives (TMIs) to affected aircraft and their interaction with non-TMI aircraft.

It should be noted that the use of ‘spots’ are typically implemented at congested airports where there are no geographic limitations on the placement of spots. Certain airports like SFO do not employ spots in terminals where pushing back from the gate places the aircraft in the active movement area.

However, the scheduling algorithm can designate this gate pushback location as a spot to initiate scheduling calculations. The authors would like to point out the differences between the physical designation of the spot and the logical definition used by the scheduler (that of entry into the active movement area).

Shifting of Delay Absorption Location

The first phase of research investigated the potential deployment of departure metering at spots and runway departure queues using optimization techniques, with the primary users being the tower air traffic controllers. Combined, these two metering points can alleviate ground congestion and minimize fuel burn and environmental impact, such as from taxiway stop-and-go conditions. But there is a cost, as the congestion problem has been transferred from the taxiways and departure queue into the ramp area. Thus, the benefits of this approach must be examined.

This ConOps assumes that advanced scheduling information can be made available to the air carriers. The flight operators can take appropriate actions to manage their ground fleet to meet the spot times. While aircraft are being held in the ramp area, air carriers can deploy various means to reduce fuel burn while meeting the spot metering times. If, for example, the airlines know 15–20 minutes in advance that an aircraft is going to be delayed 20 minutes and is sequenced 12th at the spot, ramp controllers can take some fuel-saving options, which may include holding the aircraft at the gate in addition to using ground outlet power, if available. If the gate is not available, then the aircraft may be moved to a holding area, with all engines off. Other similar options may be available to the airlines, but are heavily dependent on airline operational procedures, airport geometry, and terminal layout. Conversely these options are limited once the aircraft enters the active taxiway (or departure queue), and is subject to stop-and-go conditions during congested periods.

Showing the feasible implementation of surface metering using optimization techniques represents the first phase of the SARDA research. The second phase, which will be the subject of the follow-on research, will investigate extending the spot-metering concept into the ramp area, possibly to include ramp area management. The SARDA researchers realize that in order for this operational concept to achieve maximum benefits, participation from airline operators will be required. Phase two will take the perspective of the air carrier and will investigate ways to manage aircraft such that they will meet the spot metering times. This phase of research will involve access to some air carrier's data, such as aircraft readiness states, and the carrier's operational procedures. Other factors will include collaboration with the SARDA scheduler and involve some aspect of ground-side or surface collaborative decision making (CDM).

This report primarily focuses on the first phase of the SARDA research. The two phases of research complement each other, approaching and providing solutions from two perspectives, ATC and airlines.

Development of Possible Technical Automated Solutions

Automation to Support Multiple Objective Problems

In current airport surface operations, most of the above decisions are made 'on-the-fly' by the controllers, and are based on simple rules as well as controller experience. It is possible that with increasing traffic, the decision-making process can be aided with Decision Support Tools (DSTs). Controllers are trained to manage active traffic; with increased traffic, some of the reactive and tactical actions they employ may not offer the 'best' decision for the overall system. Sometimes, the best course of action may prove counterintuitive to the user, but may offer system-wide benefits. Furthermore, there is a need to model the above decision-making process to incorporate and satisfy multiple objective criteria, like reducing delays as well as environmental impacts. There will be a need to provide solutions that can meet multiple objectives and users (terminal and en route controllers), as surface traffic management becomes more complex and tightly integrated with other ATC domains.

Past and ongoing research addresses some aspects of the entire decision-making process (refs. 5, 11–15). The purpose of the DST for airport surface operations is to provide scheduling advisories to the controllers and aid in their task of controlling aircraft on the airport surface, while improving efficiency and minimizing negative environmental impact. The surface management DST may provide the following advisories: 1) for the ground controller, the release schedule (e.g., sequence and time) of departure aircraft at the spot, taxi route, and departure runway for each departure aircraft; and 2) for the local controller, the runway queue assignment, takeoff sequence and time, and runway crossing schedule for arrival aircraft.

At a basic level, ground controllers currently operate in an opportunistic fashion; for departures that have pushed back and are heading to their assigned spots, controllers clear the aircraft onto a taxiway as soon as possible. In busy times, this may result in congestion on the taxiways and in the departure queue area. Future operations using SARDA will assign a majority of delays to be taken at the spots, thus reducing the number of stop-and-start operations. This, coupled with more efficient departure release/runway crossing planning, will result in improved surface operations.

Controllers are trained to control traffic with separation as the primary objective. Factors that can affect their control style may include: airport throughput, flow management plans (i.e., Ground Delay Program (GDP), Ground Stop (GS)), and fairness of service between different airlines. Furthermore, ground and local controllers have not traditionally been tasked with providing overall surface operations that can lead to overall system efficiency. This is where the SARDA concept and tool may supplement their control model, by implementing optimization techniques that take into account multiple objectives, such as reducing the number of stop-and-go conditions, preserving or increasing throughput, and reducing fuel consumption and emissions.

Unified Models and Integrated Solutions

The technical approach to model the decision process is based on a mathematical framework of optimization. The most optimal solution method would be to consider all the decision factors within the same framework, because there are interdependencies among them. For example, consider the clearance for entering the taxiway from the spot: aircraft bound for an over-subscribed departure fix could be held back at the spot so that taxiways, as well as runway queues, are not crowded. Addressing all the interdependencies in a single framework is a key to a globally optimal solution, and for this reason unified models for a given time horizon have been developed (refs. 12,13).

However, dividing the entire problem into parts, solving each part separately, and then integrating these solutions has significant benefits:

- A unified model that solves a larger problem suffers from increased computational times.
- Many optimization models solve the problem over a limited time horizon, with uncertainty being handled through frequent recalculation. Large deviations from the plan would require quick recalculation, which might be easier in integrated solutions, especially when only a sub-problem requires recomputation.

Given the relative merits of integrated and unified approaches, the concept presented here is based on an integrated approach. With the high degree of uncertainty in prediction and control of aircraft, frequent recomputation becomes necessary and, hence, integrated approaches perform well.

Two sub-problems are identified based on the current-day roles and responsibilities of the Ground Controller (GC) and Local Controller (LC). Some major tasks regarding departures that tower controllers are responsible for include release of aircraft from the ramp area into the taxiway (GC responsibility), and runway operations for both takeoffs and runway crossings (LC responsibility). The scheduling functions designed to address each sub-problem have been named the Spot Release Planner (SRP) and Runway Scheduler (RS). Further, it is possible to combine the two problems into a single scheduler, which would be the unified approach described earlier. This unified scheduler is called the Taxi Scheduler (TS). Figure 2 shows the areas of operations for the surface algorithms (SRP and RS). Detailed descriptions of each scheduler/planner are presented in the following sections.

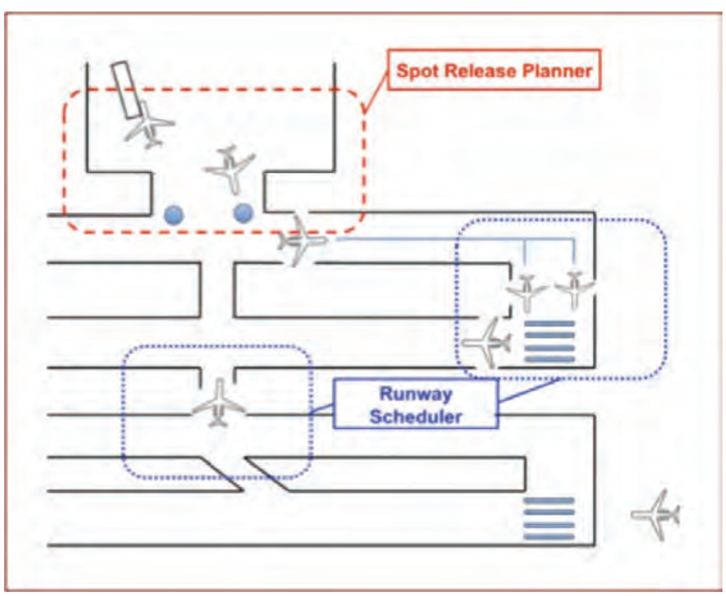

Figure 2: Operational domain of surface scheduling algorithms.

Proposed Core Scheduling Models

The sub-problems that constitute the core scheduling models are: Spot Release Planner (SRP), Runway Scheduler (RS), and Taxi Scheduler (TS). Each scheduler is formulated as a deterministic optimization problem with different objective functions and decision variables.

Spot Release Planner (SRP)

The pushback sequence and spot release sequence have been identified as potential control points for departure operations (ref. 24). A possible scheme to optimize departure operations is to hold aircraft at the gates and spots and release them "at the right time." The Surface Management System (SMS), a surface decision support tool, currently employs a heuristic to sequence aircraft at the spots (ref. 25). Further, the concept of Collaborative Airspace Surface Metering (CASM) has also been introduced and empirically studied to assess the benefits of controlled pushback in efficiency and resulting environmental benefits like reduction in emissions (ref. 26). However, in these studies there is a gap in optimally addressing the access to the taxiway system itself through spots or gates. Moreover, the issues of robustness and computational costs during implementation have not been adequately researched.

These issues were addressed by developing an SRP (ref. 27). An algorithm is proposed for calculating the spot and gate release times for the departure aircraft. Further, a taxi-routing scheme is proposed, which, in conjunction with the above spot/gate metering, avoids unnecessary congestion at the taxiway and departure queues. Delays at spots could potentially be more fuel efficient than delays at taxiways and departure queues. For example, pilots could power down one or more engines at the spot, or with advance knowledge of release times, or airlines could opt to keep the aircraft at the gates (depending on gate availability) using ground power instead of auxiliary power units, thus resulting in further fuel savings. Besides reducing delays, this proposed algorithm reduces the number of stop-and-go situations, reducing the number of "high-thrust" events, and thereby further improving fuel consumption.

The objective of SRP is to generate an optimal schedule for aircraft release from the spot that is aimed to achieve maximum runway throughput of the departure flights (i.e., the takeoff time of the last aircraft) in the planning horizon (ref. 27). The SRP inputs are:

- Estimated spot arrival times of departing aircraft.
- Assigned spot and runway for each aircraft. This information is used to predict the nominal route to be used by the aircraft.
- Type (or weight class) of each aircraft to be scheduled, along with required wake vortex separation criteria for takeoff for each weight class.
- Other separation criteria, e.g., miles-in-trail (MIT) restrictions applied to aircraft pairs flying over the same departure fix.
- Approximate taxi time for each departing aircraft.

- Any assigned time window of takeoff for departing aircraft (if any), such as Expect Departure Clearance Times (EDCTs) for flights under a Ground Delay Program (GDP), or any other Traffic Management Initiative (TMI) constraints.
- Parameters for running SRP, such as a rolling planning horizon, which could include overlap times and a discounting scheme, if applicable.

SRP provides the optimum sequence of spot release and approximate release times as output. SRP operates at two different planning horizons: SRP Long Term (SRP-LT) and SRP Short Term (SRP-ST). The motivations and benefits of these schemes are:

- SRP-LT calculates the optimal spot release schedule for aircraft that are scheduled to push back and reach the spot approximately one hour in the future with a planning horizon of 15 minutes. The larger look-ahead time allows for certain collaborative decision making between ATC and airlines, such as gate pushback and ramp area control in coordination with arriving aircraft.
- SRP-ST works in the immediate time window of up to 15 minutes and accounts for any uncertainty in the airline schedule, ramp operations, etc. The fast running time of the algorithm allows for update (as required) of spot release times based on new estimates of spot arrival times provided either by the tool or direct updates from the airline.

The objective and most of the inputs for the two models will be the same. An off-line testing conducted by the team shows average improvement of 8 to 15 percent in overall system performance compared with the results from the system without SRP for a simple case with 20 aircraft in a 15-minute planning horizon. Detailed descriptions of the algorithm and test results are found in reference 27.

SRP offers the following benefits:

- It provides a mechanism for delaying the aircraft at the spot rather than at the departure queues, resulting in less congested surface traffic without sacrificing runway throughput. This will reduce the workload of the controllers as well as pilots. In addition, average taxi time can be reduced because aircraft will taxi at slightly higher taxi speeds with less stop-and-go situations. This results in fuel savings and less emissions and noise.
- SRP can provide a tool for potential collaborative decision making on gate pushback for departures with airlines, and with Air Route Traffic Control Center (ARTCC) and/or Terminal Radar Approach Control (TRACON) facilities for arrival aircraft, such as coordinated touchdown times. However, more research is needed in order to explore the mechanism of collaborative decision-making.
- SRP provides a hypothetical maximum throughput that can be used as an upper bound for other schedulers, resulting in an increase of computational efficiency.

Of the two concepts, only the SRP-ST was implemented in the current SARDA simulations. In the December 2009 simulations, the two stages of SRP-ST as described (ref. 27) were implemented. The first stage was solved using a mixed integer linear program (MILP), whereas a simple linear program (LP) was used for the second stage. In the March and April 2010 simulations, a modification of the dynamic programming (DP) approach (ref. 15) was used for the first stage of

SRP, with the second stage remaining the same. The reason for using a different optimizer was to test the compatibility of the SRP algorithm with different optimization engines.

Runway Scheduler (RS)

Aircraft departing from an airport face numerous constraints in the scheduling of their departure times. These constraints include wake vortex separation for successive departures, departure fix MIT restrictions, and time window or prioritization constraints for individual flights. Furthermore, departure runway operations also include runway crossings by arrival aircraft needing to cross the departure runway and destined for the terminal gates. Efficient scheduling of departure operations requires scheduling runway crossings and departures simultaneously. Thus, determining runway queues for individual aircraft, and scheduling departures as well as arrival crossings within the same generic framework, would potentially improve efficiency and throughput of overall surface operations at busy airports.

RS manages the operations of a single departure runway, scheduling takeoffs as well as runway crossings. The scheduler must satisfy constraints such as wake separation criteria, MIT restrictions, and EDCT. Different optimization problems can be formulated based on the objectives of optimization. A few candidate objectives are:

- Minimize system delay by minimizing total time spent by all aircraft in the queuing area in a given planning horizon.
- Minimize the maximum delay spent by any aircraft in the queue (i.e., a fairness objective).
- Maximize runway throughput by minimizing the departure time of the last aircraft in the departure sequence.

The optimal schedules in the preceding three cases need not be the same. Identification of the preferred objective would require trade studies, inputs from the system users (e.g., airlines) and air navigation service providers (e.g., tower controllers), and environmental considerations. Various optimization formulations for RS have been developed using a mixed integer linear program (refs. 14, 28) as well as dynamic programming (ref. 15), and performance evaluated for various traffic levels at DFW. The analysis results indicate that system delay was the better objective than throughput or maximum wait time.

The RS solves the deterministic problem for a given planning horizon and handles uncertainties during successive runs by employing a rolling planning horizon. The inputs for the RS are:

- Configuration of departure queues (i.e., number of queue lanes and usage).
- Weight class of each departure aircraft.
- Separation criteria for departure aircraft.
- Any constraints on usage of queue.
- Runway queue entry time for each aircraft.
- Intended takeoff times of individual departing aircraft.
- Runway crossing windows (defined in seconds) of arrival aircraft.

Consequentially, the RS provides the following outputs:

- Runway queue assignment for each departure aircraft.
- Sequence and timing for takeoffs for each aircraft.
- Sequence and timing of active runway crossing.
- Runway exit assignment for arriving aircraft when applicable.

Implementation of the RS as a near-term decision support capability for the local controller may require some changes to the responsibility and workload of the user. For example, RS can provide the local controller with the takeoff and runway crossing sequence advisories. In addition, a runway queue assignment advisory may be added. However, the timing advisory for takeoff and runway crossing operations is not a likely candidate for a near-term or midterm capability due to the uncertainty of calculating taxi operations.

Because RS provides an additional decision for each departure aircraft (i.e., which queue to join in cases when multiple queue lanes are available), the communication between the pilots and the controller may be slightly increased. However, the controller is not required to communicate with multiple aircraft at the same time because departures are handled sequentially in nature. Runway queue entry times can be provided by a taxi scheduler (when available) or by a simple trajectory prediction function of the tool based on surface surveillance data. Similarly, runway exit suggestions can also be communicated to the pilot over voice.

A mixed integer linear program (MILP) for deterministic runway usage scheduling has been developed (ref. 28). The model is generic and can be used for a variety of cases with different methods of handling the queuing area. The MILP explicitly considers separation criteria along with additional constraints and includes an optional prioritization scheme for relevant aircraft. Multiple objectives are used, and simulations indicate substantial benefits over a basic first-come, first-served (FCFS) rule. Computational improvements to the basic MILP are also provided; however, in almost all cases the solution times are large, primarily due to poor bounds (i.e., the optimal solution was found fairly quickly, and a lot of time was spent in proving optimality for this solution by changing the lower bounds). Computational improvement for this MILP is the subject of ongoing research.

Given the need for fast computations in the March and April 2010 simulations, the departure queues and runway exits were assigned by the controllers and were taken as input to the algorithm. For this reduced problem, a modification of the dynamic program in reference 15 was used; this model produced computationally acceptable solutions.

Taxi Scheduler (TS)

In current airport surface operations, the ground controller is responsible for controlling taxi operations of aircraft (arrivals and departures) between runways and spots or gates. The controller issues taxi clearances to aircraft and makes decisions on aircraft movement. These decisions are then communicated to transient aircraft to make the surface traffic safe and efficient. Although controllers augment their decisions by simple heuristics based on their experience, observations and data analysis of airport surface traffic indicate that a majority of the decisions made by the ground controller on the taxiway are still based on an FCFS rule (ref. 29).

Researchers have modeled taxi schedulers for surface operations, including ramp, taxi, and runway operations using various optimization methods (refs. 11-13,30). Ideally, the optimization model can provide a complete taxi solution for each aircraft to the users (i.e., pilots and controllers), including routes and timing at each node on the route, which are essentially the 4-D trajectory-based surface operations. Different objectives are being studied with regard to computation time, solution quality, and integration issues. Candidate objectives are to:

- Minimize total taxi time of all aircraft in the system.
- Minimize total time spent by all departures at spots and arrivals at the runway crossing queues.
- Minimize the maximum departure time spent by any aircraft at the spot (for departures) or runway crossing queue (for arrivals).
- Maximize runway throughput by minimizing the departure time of the last aircraft in the runway sequence.

It should be noted that using the first objective alone might not be practical because the taxi schedule would generate results using the aircraft's maximum taxi speed, without considerations for throughput or the delay of individual aircraft. The result may impose an unreasonable utilization of airport resources. However, this objective can be used as a linear combination with other objectives. Appropriate choice of the coefficients could be made based on stakeholder inputs, and trade studies will be needed to recommend those coefficients.

The inputs for the TS are:

- Type of aircraft and maximum taxi speed on taxiway links.
- Separation criteria at runway (e.g., wake vortex, MIT restrictions).
- Safety constraints on taxiway nodes and links (e.g., no head-on collision, no overtake) .
- Route to be used by aircraft (for a static route problem only).
- Time window of estimated gate pushback or spot arrival times.
- Estimated touchdown time of arrival aircraft.
- A range of travel times for each aircraft on each link from analysis of historical data and/or environmental efficiency.

Outputs are:

- Gate pushback times or spot release times.
- Takeoff times of departure aircraft.
- Runway crossing time for arrival aircraft.
- 4-D trajectory for each aircraft.

It appears that TS alone can solve for the traffic-scheduling problem covering the entire airport surface. Such a solution offers an equivalent to a combined Spot Release Planner—Runway Scheduler (SRP-RS) system. It is possible that a unified scheme based on TS could be used to provide the same functionality as an integrated SRP-RS system. However, it may not be practical to use it as a sole surface optimizer mainly due to computational performance and current ability to capture uncertainty in the system from initial internal finding. Moreover, certain deviations could be addressed by recalculating only one sub-problem, with little or no change required to the other sub-problem. In contrast, the unified approach would have to recalculate for the entire airport. Application of TS as a unified solution was a direction for future research and was not a component of the April 2010 simulations.

Assumptions and Requirements

A framework of any concept is built upon assumptions and requirements. The implementation time frame is an important consideration in developing assumptions and requirements. It frames the solutions based upon estimates of available technologies including surveillance, avionics, and traffic demands. As a reference, in the development of the SARDA concept, the 'near-term' is defined as the time frame with the proposed implementation phase between 2013 and 2015; 'midterm' is defined as between 2015 and 2018; and 'far-term' is defined as the time frame with the proposed implementation phase with considerable automation for the years 2019 to 2025 (ref. 31). For the late near-term/early midterm concept described here, the following assumptions are made:

- Airlines or airport authorities manage ramp area operations and, therefore, ATCT does not have direct control of gate pushback of departure aircraft.
- The ground controller has authority to hold departure aircraft at spots within a specified time interval before the aircraft are cleared to move into taxiways.
- Voice communication is still the main mechanism for relaying commands between ATCT controllers and pilots.

The technology requirements are as follows:

- Aircraft positional data is available in the ramp area.
- Prediction of pushback times of departure aircraft is possible and available.
- Prediction of arrival times of departure aircraft at runway queue entrance is available.
- Prediction of arrival times of landing aircraft at runway crossing queue is available.
- Execution of algorithms should be fast enough to support real-time decision capabilities.

The first and second requirements are to provide accurate predictions of spot arrival times for departure aircraft as inputs to the decision support system. It is assumed that state-of-the-art methodology is used to ensure the accuracy of the prediction capability during the intended deployment time frame. While it may sound desirable to have a surveillance system that provides complete coverage of the ramp area, in many airports such coverage would require significant infrastructure investment to airlines or airport authorities. As an alternative solution, participating airlines or airports can fulfill these requirements by providing the required data (predicted pushback time and consequent spot time) to the decision support system with a data exchange system.

Looking further out, one can envision additional requirements to address the far-term concepts, though far-term concepts are not currently being addressed in SARDA research. For completeness, the team has identified additional requirements to address in the far-term concepts:

- Availability of datalink between controller and flight deck. This would be used to provide 4-D trajectories.
- Comprehensive surveillance on the surface including the ramp area.
- A robust framework for conformance monitoring with respect to generated schedules.
- Tools for conflict detection and resolution on the surface.

Example of an Implementation Concept Using the Integrated Approach Scheduler

An SRP model provides sequence and time window of departure releases at spots to the ground controller. Similarly, the RS provides sequence and time window for each takeoff to the local controller. A combined model of SRP and RS will provide advisories to both ground and local controllers. The concept presented here is built upon this combined SRP-RS scheme. In this framework, SRP-ST is used to provide the spot release times for departure aircraft. RS is used to generate takeoff clearances for departures and runway crossing clearances for arrivals. All decisions regarding aircraft movement on taxiways are at the controllers' discretion. The step-by-step walkthrough is presented below:

1. Fifteen minutes in advance (to gate pushback or touchdown), the following information for all the arrival and departure aircraft are input into the decision-support system: weight class, departure fix restrictions, EDCTs, ground delay programs, and MIT. Changes in this information may trigger recalculation, and simulations would provide insights on the magnitude of changes, which the system can handle without recalculation.

2. Ramp controller or the trajectory prediction module for ramp area movement provides estimated times of arrival (ETAs) of departure aircraft at spots for the next 15 minutes. These ETAs are used by SRP-ST, which provides the controller with the optimal spot release times for that 15-minute period. A timeline or a datatag on the map display provides the necessary advisory to the ground controller.

3. A rolling planning horizon method is used to handle deviations from spot ETAs, with a predetermined overlap period (say 5 minutes). If a deviation occurs in some aircraft before a planned recalculation, the remaining aircraft are released as before, whenever applicable, until recalculation.

4. There is no change in taxi operations from current procedures.

5. SRP-ST generated spot release; airport surveillance and trajectory prediction based on FCFS are used to provide ETAs to departure queues for the next 15 minutes. The arrival decision support tool, such as the Traffic Management Advisor (TMA) provides estimated touchdown times of arrival flights for the next 15 minutes, which would be inputs to RS.

6. RS uses above data to generate runway exit suggestions and crossing times for arrivals, as well as queue assignment and takeoff times for departures. These advisories are provided to the local controller through a list or a datatag on a map display, and are communicated to the flight deck over voice.

7. A rolling planning horizon method is also used in RS, with a predetermined overlap period (say 5 minutes). However, if the runway exit suggestion or queue assignment is not met (for example, due to pilot decision), an immediate recalculation for the next 15 minutes is done.

TECHNICAL APPROACH

Spot Release Planner (SRP) Details

The SARDA concept aims to provide metering advisories to two groups of users, the ground and local controllers, with the Spot Release Planner (SRP) presenting the ground controller with spot release times and sequences. In a complementary fashion, the local controller receives runway departure sequences from the Runway Scheduler (RS). This section provides additional detail about the SRP and RS.

The objective of the SRP is to generate an optimal schedule for aircraft release from the spot while aiming to achieve maximum runway throughput for departures (ref. 27). SRP calculates for an optimal spot release schedule in two stages. In the first stage, an optimal departure schedule at the runway for a set of incoming flights is generated with an objective of maximizing runway throughput:

$$\min(\max_{i \in F} t_i) \tag{1}$$

where t_i is the calculated takeoff times for flight *i,* and *F* denotes all flights. For each flight, an estimated time of arrival (ETA) at its assigned spot, and an estimated taxi time between spot and assigned runway via one of the standard taxi routes, are the main inputs to the algorithm. In addition, constraints, including wake separation criteria and other time/distance constraints, such as a MIT restriction over a common departure fix and Expect Departure Clearance Time (EDCT) due to a Ground Delay Program (GDP), are applied. The optimization problem of this first stage can be formulated either as a mixed integer linear program (MILP) or by using dynamic programming (DP). Both formulations were evaluated, but the DP was the preferred approach mainly due to its availability over commercial optimization solvers.

The second stage of the SRP is to determine optimal times to release aircraft from assigned spots to meet departure schedules. Depending on the complexity of the taxiway geometry and the decision whether to incorporate variable taxi speeds or arrival traffic, the problem can be formulated as either a reduced MILP or a linear program (LP). For surface traffic at Dallas/Fort Worth International Airport (DFW), all of three standard departure taxi routes (i.e., K-EF, K-EG, L-EH shown in figure 3) have a very simple structure with almost equal taxiway lengths. Therefore, spot release times for each aircraft can be calculated simply by subtracting the estimated taxi time from its scheduled takeoff time.

$$T_i = t_i - \tau_i \tag{2}$$

where T_i is the spot release time and τ_i is the estimated taxi time of the i^{th} flight. An additional constraint due to uncertainties of operation is to have a small number of aircraft in the departure queue (e.g., runway queue size < 6) to ensure that there are no gaps in the actual departure schedule.

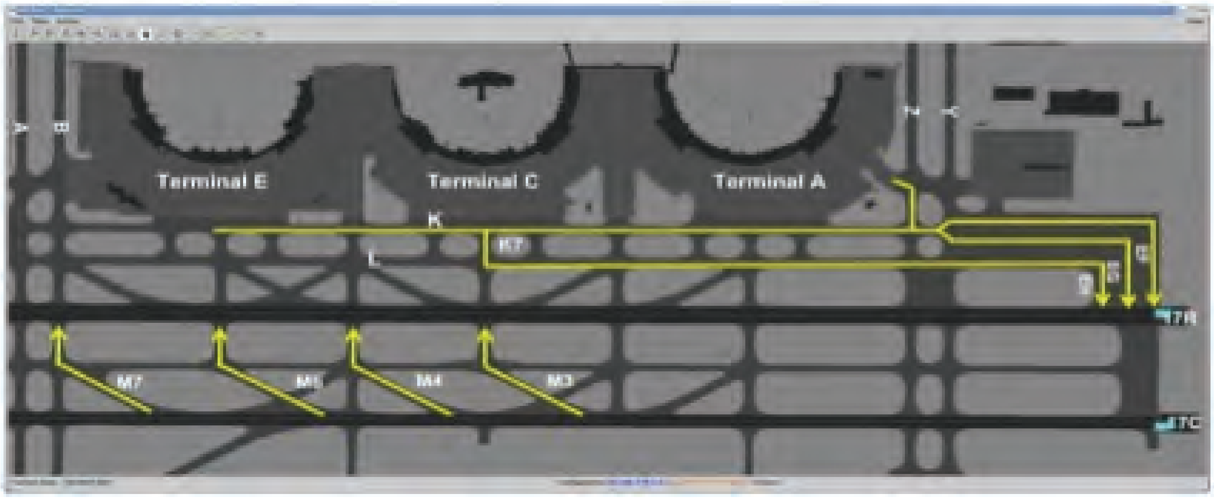

Figure 3: Departure taxi routes, departure runway queue, and runway crossing structures of east DFW.

Key design parameters considered for the SRP algorithm are:

- Planning horizon—the future planning time interval for the algorithm.
- Freeze sequence—number of aircraft for which the spot release sequence is fixed across consecutive calls of the algorithm (e.g., first three aircraft in the sequence).
- Equity—a parameter to be used to prevent a particular aircraft or type of aircraft from being penalized in subsequent optimization cycles.
- Priority aircraft—specifies priority in takeoff sequence (e.g., an aircraft in an emergency situation).
- Maximum spot delay or spot queue size—a parameter to be used by the algorithm to prevent a queue from forming at a certain spot.
- Runway queue size—a parameter that specifies the number of aircraft allowed in the runway queue at any time.
- Airport operating points—Airport Departure Rate (ADR) that will affect the optimization of departure schedule.

Executing the algorithm periodically to generate new optimization solutions mitigates uncertainties in taxi speed, pilot responses to controller taxi clearances, and interaction among taxiing aircraft. In the simulation, the SRP algorithm was executed every 40 seconds with a rolling planning horizon of 15 minutes.

Runway Scheduler (RS) Details

The motivation for and design of the RS were based on an evaluation of the role of the local controller. The local controller strives for efficient runway operations by sequencing takeoffs, considering various factors such as aircraft weight class, departure route, departure fix constraints, Area Navigation (RNAV) procedures, and others. The local controller is also responsible for managing crossing operations of arrival aircraft. With multiple runway queue lanes and multiple crossing points at DFW as shown in figure 3, the sequence decision made by the human controller may be far from optimal due to complexity. A previous study at DFW showed that the average stopped time of aircraft in crossing queues during busy traffic times was over 2 minutes, which turned out to be the most significant contribution to the taxi delay of arrival aircraft (ref. 16). Therefore, the objective of the RS is to provide an optimal sequence for takeoffs and runway crossings of arrival aircraft.

Previous optimization approaches were developed and tested for various configurations of runway queue structure (refs. 5,12,17). Rathinam et al. (ref. 15) developed a generalized dynamic programming formulation and successfully solved the departure-scheduling problem of a single runway with multiple queue lanes. Optimal solutions to schedule 40 aircraft for an hour were obtained in less than 1/10th of second of computational time. For SARDA, this algorithm was extended to include constraints for runway crossings. In order to incorporate runway crossing constraints, the algorithm requires estimated arrival times of aircraft at hold lines for crossing, as well as travel times for crossing at different speeds.

The requirement for estimated crossing times and travel times necessitate a trajectory prediction function, which should include the capability to predict the runway exit an aircraft would use. In order to make the problem simple, runway exits were assigned by the local controller before aircraft landed on the runway. The algorithm also allows multiple crossings at the same time.

The inputs to the RS algorithm include ETAs of departure aircraft at their assigned queue lanes (i.e., EF, EG, or EH as shown in figure 3), aircraft type, and wake vortex separation criteria. Similar to current DFW procedures, the ground controller issues a taxi route clearance that includes the departure queue lane assignment. Therefore, the algorithm receives the queue lane information from the controller (via keyboard input). Other constraints such as Traffic Management Initiatives (TMIs) departure route, EDCT, and RNAV, were not incorporated into the algorithm at the time of simulation. They will be addressed in future study. The dynamic program used the Pareto-optimal solution of both throughput and departure delay; throughput and departure delay are defined below in expressions (3) and (4) respectively:

$$\min \sum_{i \in F} (t_i - \alpha_i) \tag{3}$$

$$\min(\max \quad t_i) \tag{4}$$

where t_i is the calculated takeoff time and α_i is the earliest release time for flight i ($i \in F$). Similar to the SRP algorithm, key design parameters to consider for the RS were identified as follows:

- Planning horizon—the future planning time interval for the algorithm (e.g., 15 minutes).
- Maximum departure delay and maximum arrival crossing delay—parameters to be used to prevent a particular aircraft or type of aircraft from being penalized in subsequent optimization cycles.
- Priority aircraft—specifies priority in takeoff/crossing sequence.
- Crossing queue size—specifies the maximum number of aircraft allowed in each crossing queue.
- Maximum simultaneous crossings—specifies the number of crossings allowed simultaneously from a single crossing queue.
- Similar to the SRP, the RS needs to be executed frequently to generate new solutions in order to accommodate uncertainties. In the simulation, the RS algorithm was executed every 40 seconds with a rolling planning horizon of 15 minutes. Note: the update cycle of the RS and SRP does not need to be synchronized. In fact, the updates were offset by 20 seconds, so as to not cause potential network congestion.

HUMAN-IN-THE-LOOP SIMULATION EVALUATION

Background

This section focuses on the human-in-the-loop (HITL) simulation activities that used retired ground and local controller participants to help evaluate some of the SARDA features. Details on user interface design, training, and tool evaluation tools are presented here.

The utility of an automated system can be evaluated in terms of the performance of a human user when paired with that system to perform realistic tasks, which may in turn be influenced by a number of factors, including the ease with which that system can be used as well as the users' desire and willingness to use the system. "Ease of use" refers to more than simple "buttonology" and training. System usability can be defined by a cluster of factors, including the system's contribution to task efficiency, the frequency with which the user makes errors, the ease with which users can recover from errors, and the satisfaction the operator has when using the system (ref. 32). To the extent that a given system lacks usability in any of these critical parameters, the user's performance with that system can be degraded (ref. 33).

Well-designed tools that perform cognitively difficult tasks for a human can reduce the user's workload associated with performing tasks such as information acquisition and analysis (ref. 34). A tool that is poorly designed, however, can add to task complexity, increasing workload beyond manageable levels and reducing the operators' task performance (refs. 35,36).

Furthermore, well-designed automated systems can enhance an operator's situation awareness (SA)—their mental model of the current state of the operational environment (ref. 37). However, automation can reduce SA such that the human operator has a diminished ability to detect automation failures and to understand the state of the system sufficiently to take over operations manually when needed (ref. 37). Users of automation sometimes struggle with understanding what the automation is doing or why it is taking/suggesting a certain action. Significant errors can occur when an operator struggles to ensure congruence between what they think the automation is doing and what they want it to do (ref. 38). Decision support automation can interact with information evaluation processes in such a way as to diminish an operator's capacity to make a decision without the automation, which can lead to increased errors when the automated system is wrong or when the automation is deactivated (ref. 39).

Outcome measures of user/system performance can provide indications of the usefulness of the systems in helping users be more effective and efficient, performing their tasks more accurately and more quickly. Taken together with assessment of users' workload, SA, and usability, these performance measures can paint a rich picture of a system's overall utility.

Although this simulation was not intended to evaluate field-ready technology, it provided controllers with exposure to the SARDA tools and served as a venue for them to give early feedback on the effectiveness of the technology. This feedback can have a direct impact on system research and development activities.

General Methodology

The SARDA evaluation ran from April 22–May 7, 2010. The first 2 days of the evaluation focused on controller and pseudo-pilot familiarization with the simulation environment and controller familiarization with the SARDA tools. The testing phase of the evaluation lasted 10 days. Each testing day comprised six 45-minute scenarios, each of which was followed by a battery of questionnaires. On the afternoon of the last day of the evaluation, controller participants engaged in a structured group workshop to discuss their impressions of, and provide feedback about, the SARDA systems and the evaluation procedures.

Study Participants

Two recently retired air traffic controllers participated in the study. Both participants had over 25 years of air traffic control experience, each with over 20 years of experience working in the Dallas/Fort Worth (DFW) control tower. Both participants had retired from DFW within 3 years prior to study participation. Neither participant was familiar with the SARDA concepts or tools prior to the study.

Research Team

Two human factors specialists and one retired air traffic control tower (ATCT) controller, all familiar with the SARDA concept and tools, conducted participant training and served as observers during the study. In addition to training, observers' responsibilities included real-time observation of participants interacting with the SARDA tools, administering questionnaires, and conducting an end-of-study debrief with participants.

Training Material

Controller participant training took place over 2 days prior to the start of data collection. Controller training comprised both classroom (0.5 days) and hands-on (1.5 days) familiarization with the simulation environment and procedures as well as the SARDA concept and tools. Hands-on training included exposure to all advisory and traffic conditions present in the data collection trials. Observers from the research team were present throughout training to answer participants' questions. The charts used in the classroom training can be found in *Appendix C: Controller Training Material*.

Questionnaires

Following each data collection run, three brief questionnaires were issued to the controller participants, and one questionnaire was issued to the pseudo-pilot participants. At the end of the experiment, controller participants were also asked a series of evaluative questions about the SARDA concept and tools, as well as about the simulation as a whole. Each of these questionnaires is described in more detail below. *Appendix H: Human Factors Questionnaires* contains the sample questionnaires.

Controller post-run questionnaires

Workload. Workload measures were developed to assess the type and degree of perceived mental demands associated with using the SARDA advisories. Perceived workload was measured using the NASA Task Load Index (TLX) scale (ref. 40). The NASA TLX is a multi-dimensional scale of workload that can provide both a global measure of workload, as well as a measure of workload along each of the subscales, which include mental demand, physical demand, temporal demand, performance, effort, and frustration. The NASA TLX, a widely used scale for assessing workload, has demonstrated sensitivity at low levels of workload, and is relatively easy to understand and use. A global workload score can be determined from an average of ratings on the various subscales.

After each run, the controllers were asked to fill out the workload questionnaire via a laptop computer. The controllers answered the questions by indicating their selection on a non-numbered horizontal scale. The scale ranged from low (left anchor) to high (right anchor). During analysis, the scaled was converted to fit between the values of zero (low) and one (high). The human factors findings are presented in the *Results and Findings* section. In addition, the list of questions presented to the controllers is contained in *Appendix H: Human Factors Questionnaires*.

During the training phase of the study, the controller participants completed a worksheet designed to assess the relative importance of each of the TLX subscales to performance of real-world ATC tasks. The results of this assessment were used to weight each of the subscales in computing a global subjective workload score. To compute an overall workload rating, the inverse of the rating for the performance subscale was used to align the valence of all subscales. On this global workload scale, lower scores indicate lower perceived workload. System users completed this scale after each of 54 data collection runs in the evaluation.

Situation Awareness (SA). Situation awareness may be assessed in a variety of ways. Each type of SA measure has strengths and weaknesses and may provide different sorts of information. For example, subjective SA measures, such as the Mission Awareness Rating Scale (MARS) (ref. 41) have an advantage of assessing an individual's personal level of SA, are easily administered, and are relatively unobtrusive to collect. However, individuals may not know what information they are unaware of and their judgments may be influenced by self-assessments of their own performance. Similarly, direct objective SA measures, such as the Situation Awareness Global Assessment Technique (SAGAT) (ref. 42), have the advantage of providing more objective and less biased estimates of SA, but are relatively obtrusive and require considerable prior analyses to develop valid measurement protocols. Given that different SA measurement approaches may provide different types of information or be more acceptable in certain situations, a measurement strategy using multiple SA approaches is desirable. In this study, both subjective SA and objective SA measures were collected.

Subjective SA. The subjective SA instrument used in this study was a modified version of MARS, which consists of two subscales. One subscale assesses SA content and the other assesses SA workload. Each subscale consists of four questions that address the three levels of SA—identification, comprehension, and prediction (ref. 42). In addition, a fourth question deals with how well task goals can be identified. The four Workload Subscale questions require the respondent to indicate how much mental effort was required to identify, comprehend, predict, and decide in the given run. All questions were rated on a four-point scale. Overall subjective SA was computed by averaging across all eight items in the questionnaire. Lower scores indicate lower SA. Controller subjective SA ratings were divided by 4, for the purposes of comparison with controller objective SA ratings

Objective SA The objective SA instrument used in this study was developed using a modified version of SAGAT. Prior to the study, a series of objectively verifiable queries related to ground and local controllers' tasks and objectives were generated by human factors specialists and vetted by an ATC subject matter expert. Typically, using SAGAT, these queries would be administered during planned interruptions in task performance. However, because of limitations in the system interactions between Surface Management System (SMS) and Airspace Traffic Generator (ATG), it was not feasible to pause the simulation during a run. Therefore, the objective SA queries were administered immediately upon completion of each run, and query responses were based on what was happening in the simulation at the moment the run ended.

This modified procedure limited the assessment of level 3 SA (i.e., prediction, see ref. 42), because of difficulties with objectively verifying statements about controllers' plans once the run was over. Observers from the research team took digital photographs of the ground and local controllers' displays at the end of each run. These photographs were used to assess the "ground truth" answers for the SA queries against which participant responses were compared. The objective SA questionnaire for ground control comprised five queries, and the questionnaire for local control comprised eight queries. All responses were scored as either correct (1) or incorrect (0). Scoring criteria for each item are described in *Appendix H: Human Factors Questionnaires*. Global objective SA assessments were calculated by averaging scores across all queries for that position.

Pseudo-pilot post-run questionnaire

Workload. The successful movement of traffic in an airport environment is critically dependent on efficient interactions between controllers and pilots. Because the primary focus of the study was on controller performance, it was important to measure pseudo-pilot workload to assess potential impacts on overall system performance.

Pseudo-pilots completed the NASA TLX to assess their workload associated with each run. Because pseudo-piloting differs in potentially important ways from piloting real aircraft, pseudo-pilots were not administered the subscale weighting assessment. All subscales were equally weighted in computing a global workload score for each data collection run. Pseudo-pilot ratings were divided by 7 for the purposes of comparison with controller workload ratings. The ratings were analyzed for a total of 36 data collection runs.

Additionally, pseudo-pilots were asked to estimate the percent that each of the following factors contributed to their total workload during each run:

- Number of aircraft under their control.
- Size of the area under their control.
- Communications with ATC.
- Executing ATC commands.
- Issues with the screen/map display.

Insights based on these assessments may be used in the design and allocation of pseudo-pilot responsibilities for future studies.

Post-run questionnaire and debrief

After the completion of all data collection runs, controller participants were verbally asked a series of open-ended questions about the SARDA concept and advisories, the verisimilitude of the simulation environment, and the quality of the provided training. Participants' responses were recorded using a digital voice recorder, and were later processed and distilled by members of the research team. Participants' qualitative responses to these questions can provide insights about controllers' behaviors during the simulation, as well as areas of focus for future research and development.

Display Options

This section discusses the user display options that were investigated. The section titled *SARDA Concept of Operations* describes the ConOps and is helpful in understanding how the displays would be used. An important design concern in presenting operators with automated advisories is determining an optimal method for displaying the advice. Considerations may include the time criticality of the information, other information the operator may be integrating into the decision the advisory is supporting (which may influence where the operator is attending when the advice is presented), or concurrent tasks the operator may be performing.

To explore potential display tradeoffs, two versions of each SARDA advisory were presented to controller participants during the simulation. A "datatag" version incorporated the advisory into the datatag of relevant aircraft on the map displays. A "timeline" version presented the advisories in a separate window on the workstation adjacent to the map displays. Each of these display options is addressed in more detail below.

Ground Controller Displays—Presenting Spot Release Planner (SRP) Advisory

Datatag Advisory. In advisory and baseline conditions (Datatag and Timeline, see *Test Conditions and Matrix)*, datatag of aircraft awaiting spot release includes aircraft identification (ID), aircraft type, departure fix, and spot number. With advisories enabled, a spot release sequence number and a spot release countdown timer, both generated by the SRP, were added to the datatag as shown in figure 4. The sequence number indicated the computed optimized order in which controllers should release aircraft from the spot, and the countdown timer showed a time window for spot release (e.g., AAL9094 is first in the spot release sequence, releasing from spot 9, with 4 seconds left in the current release window).

Controllers were instructed to release aircraft from the spot in the order indicated by the sequence number when the countdown timer was between 0–60 seconds. When the release time was greater than 60 seconds, the countdown time was displayed on a blue background. Between 0 and 60 seconds, the countdown time was displayed on a flashing green background. After 0 seconds, the timer counted up in negative numbers, and the background turned yellow. When the countdown timer was greater than 300 seconds, or sequence number was greater than 20, the advisory information was not displayed in order to reduce display clutter.

Figure 4: Spot Release Planner (SRP) advisories using datatag format.

Timeline Advisory. In the timeline advisory condition, the SRP information was displayed in a window to the immediate right of the airport map display. The timeline advisory indicated the current time along with a scrolling "tape" that advanced from the top to the bottom of the window as shown in figure 5. This tape represented a view several minutes into the future (above the 23:20:00 current time mark), ticking continuously down toward the current time. Departure aircraft awaiting spot release in the ramp area were displayed in sequence on the timeline based on their SRP release schedule. The data field included aircraft ID, departure fix, and spot location (e.g., EGF4375, release from spot 22 at time 23:22, heading toward the CLARE departure fix).

Similar to the datatag information and color scheme, aircraft information was presented in blue text if the advisory indicated a spot release time greater than 60 seconds from the current time. Aircraft information turned green if the advisory indicated a spot release time within 60 seconds of the current time. If an aircraft passed the current time without being released from the spot, the aircraft information turned yellow. If the controller took no action within a given duration, the system would recalculate and reassign the aircraft a new release time. Slewing and clicking on an aircraft's data field would highlight that aircraft's information in a green box on both the timeline and the map display. Controllers were instructed to release aircraft from the spot in the sequence represented on the timeline (i.e., from bottom to top), and to try to taxi aircraft into the movement area between 60 and 0 seconds of the advised spot release time on the timeline (when the aircraft information turned green).

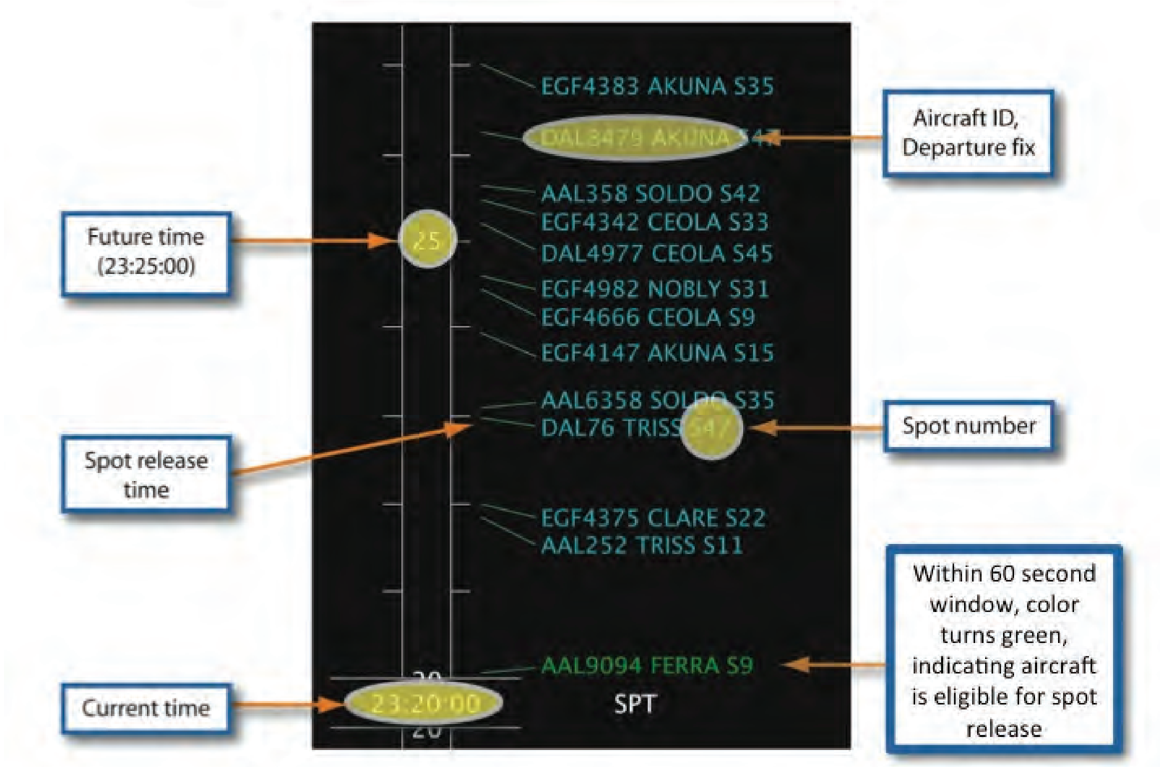

Figure 5: Spot Release Planner (SRP) advisories using timeline format.

Local Controller Displays—Presenting Runway Scheduler (RS) Advisory

Datatag Advisory. In both advisory and baseline conditions, datatags for aircraft in the Runway 17R departure queue contained the aircraft ID, aircraft type, departure fix, and assigned taxi route as shown in figure 6. The DFW Runway 17R queuing area supports up to three queue lanes, which are designated as Outer (O), Inner (I), and Full length (F). The ground controller can assign a spot release aircraft into one of these queue lanes by entering the route selection into the scheduler via keyboard entry. The local controller sees the routing data on the aircraft tag as I, O, or F.

In the datatag advisory mode, the datatag for aircraft in the Runway 17R departure queue also included a sequence number generated by the RS, displayed in white text in figure 6. The local controllers were instructed to depart traffic in the order given by the sequence number. The RS also assigned sequences to arrivals awaiting crossing of Runway 17R heading toward the terminals. If an arrival had a sequence number of '1,' that aircraft should be instructed by the local controller to cross Runway 17R prior to clearing the next departure, which would have a sequence number of '2.' Multiple arrivals might be given the same sequence number by the RS, indicating that the group of aircraft should cross the runway together. Unlike the SRP advisory, the RS advisory does not provide timing information to the controller, because the local controller does not use that type of information and it clutters the display.

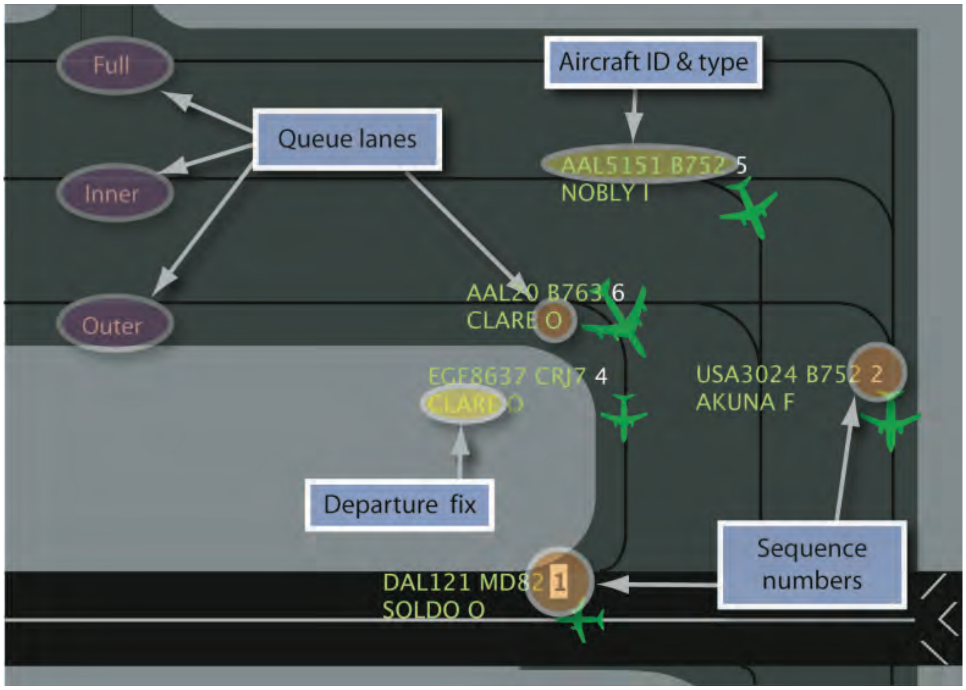

Figure 6: Runway Scheduler (RS) advisories using datatag format.

Timeline (Sequence List) Advisory. The RS Timeline advisory condition provided a sequence list format that interleaved departure with arrival runway crossing advisories in a single column (fig. 7). Similar to the ground controller's timeline, the sequence list showed a vertical column of aircraft with the first aircraft to be cleared at the bottom of the column. Figure 7 shows departures in green text, displaying aircraft ID and type, departure fix, and RS-generated release sequence number (e.g., DAL121, aircraft type MD82, departing through the SOLDO fix, has a control sequence of one). Arrival aircraft were presented in white text, showing aircraft ID, arrival runway exit, and RS-generated sequence number (e.g., DAL7209, expected to take the M6 runway exit, and third in the sequence, along with AAL144).

Initially, the local controller's timeline display format mirrored that of the ground controller. After vetting the design through subject matter experts, they found the RS-generated sequence to be useful, but the temporal component posed some adverse side effects. They felt that the temporal component introduced more workload (time pressure) to meet the departure time. In contrast, the controllers would not maneuver any aircraft if doing so would negatively affect safety, regardless of any suggested time. Hence, the temporal component was removed, which then transformed the timeline format into a sequence list format. Controllers are quite efficient in spacing aircraft between subsequent departures and arrivals; the sequence list aids in deciding which aircraft to depart next while allowing the controller flexibility to manage other ground traffic.

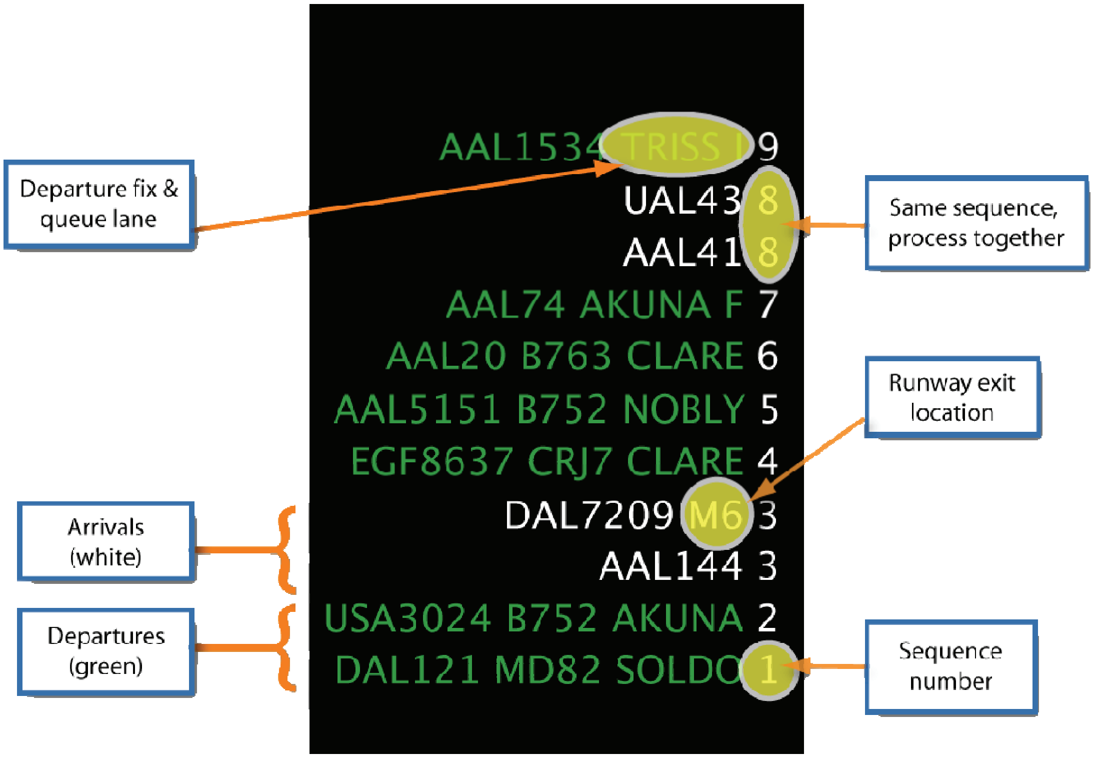

Figure 7: RS advisories using timeline format.

TEST CONDITIONS AND MATRIX

Test Variables and Matrix

The April 2010 test simulated traffic on both the east and west sides of the airport, but only had SRP and RS providing advisories to the participant controllers working the east side of DFW. West-side traffic was controlled by automation. Independent variables included traffic level, controller position, and type of advisory used, as shown in table 3.

The traffic level was rated either Normal (No) or High (Hi), with normal representing current-day traffic (airport rate of 89 aircraft/hour) and high representing about 50 percent more traffic (134 aircraft/hour). Each controller worked one of two east tower positions, east ground or east local. After each data collection run, they rotated to the other position. Lastly, controllers were asked to control traffic using one of the four control conditions during each run: Baseline-1 (B1, no advisories—controllers used their experience); Baseline-2 (B2, similar to B1 but used only during heavy traffic); Advisory enabled using Datatag (AD) format; and Advisories enabled using Timeline (AT) format. The B2 runs are highlighted in table 4 in Days 6–9. In B2, controllers were asked to meter departures from the spot without the aid of automation, and maintain no more than six aircraft in the departure queue. Their task required them to manually mimic the objective function of the SRP and RS schedulers; the B1 condition did not ask controllers to mimic the objectives of the automation.

The test matrix presented in table 4 shows the mix of test variables deployed during each run. For example, on the first run on Day 1 (G-No1-AD), controller 1 worked the Ground (G) position and controller 2 worked the Local (L), working the normal traffic condition using scenario 1 (Normal-1) with SARDA presenting advisories on the aircraft's datatag (AD). In the next run (L-No1-AT), the controllers switched the position (i.e., controller 1 at Local, controller 2 at Ground), running the same No1 scenario, with SARDA advisories shown on the Timeline display (AT).

TABLE 3: SUMMARY OF TEST VARIABLES

Variables	Values
Traffic Load	Normal (No1, No2): similar to today's traffic. High (Hi1, Hi2): 50% more than today's traffic.
Controller Position	Ground (G) Local (L)
Advisories	ON: Shown to controllers, using either the Timeline (AT) format or Datatag (AD) format OFF: Not displayed (representing baseline conditions) Baseline (B1 and B2)

Table 4 shows 59 runs, covering a span of 2 weeks of testing, averaging 6 runs per day. Three of the 59 runs were considered exploratory runs and were not considered part of the data collection test matrix. The three exploratory runs were conducted to investigate potential topics for future studies and considerations. The test matrix was comprised of 24 test cases (repeated twice) and 8 additional B2 runs, totaling 56 complete runs, with each run lasting about 45 minutes, on average.[1]

TABLE 4: SARDA DATA COLLECTION TEST MATRIX

Day 1	Day 2	Day 3	Day 4	Day 5
G-No1-AD	G-Hi2-AD	L-No1-B1	L-Hi2-B1	G-Hi1-AT
L-No1-AT	L-Hi2-AT	G-No1-AT	G-Hi2-AT	L-Hi1-B1
G-Hi1-B1	G-No2-B1	L-Hi1-AD	L-No2-AD	G-No1-AD
L-Hi2-AD	L-No1-AD	G-Hi2-B1	G-No1-B1	L-No2-AT
G-No2-AT	G-Hi1-AT	L-No2-AT	L-Hi1-AT	G-Hi2-B1
L-No2-B1	L-Hi1-B1	G-No2-AD	G-Hi1-AD	L-Hi2-AD
Day 6	**Day 7**	**Day 8**	**Day 9**	**Day 10**
L-Hi1-B2	L-No1-B1	G-Hi2-AT*	L-Hi2-B2	L-Hi2-B1
G-Hi1-B2	G-No1-AT	L-Hi1-AD	G-Hi2-B2	G-Hi2-AD
L-No2-AD	G-Hi1-B2	G-No1-B1	L-Hi1-AT	Exploratory Runs
G-No2-B1	L-Hi1-B2	L-No1-AT	G-Hi1-B1	Exploratory Runs
L-Hi2-AT	G-No2-AD	G-Hi2-B2	L-No1-AD	Exploratory Runs
G-Hi1-AD	L-No2-B1	L-Hi2-B2	G-No2-AT	

L/G – Local/Ground position
No/Hi – Normal/High traffic level
AT/AD – Advisory Timeline/Advisory Datatag format
B1/B2 – Baseline 1/Baseline 2
*Run had corrupted data, hence data set was not analyzed

[1] The authors would like to note an erratum in reference 31 where it stated that the last two runs on Day 10 of Table 4 (L-Hi2-B1 and G-Hi2-AD) were conducted to retest the conditions on Day 2— Run 1, and Day 4— Run 1. The Day 10 runs complete the data collection matrix.

Scenario Development

Two traffic load conditions, normal and heavy, were used during the data collection period. The team developed two similarly loaded scenarios for each traffic load condition, resulting in four distinct traffic scenarios. The scenario file describes the level of traffic for arrivals and departures to be inserted throughout the 45-minute simulation duration. The Normal traffic condition delivered 40 departures and 40 arrivals, while the heavy scenario inserted 64 departures and 60 arrivals. Note that the traffic count covered traffic for both sides of the airport; west-side departures used runways 13R and 18L, and east-side departures used runway 17R. Arrivals landed on the west using runways 13R and 18R while east-side arrivals landed on runways 17C and 17L. More details on scenario generation are available in *Appendix F: Historical Input Files for Scenario Generation.*

It is important that the development of the simulated traffic reflect actual day operations, at least for the Normal (N1 and N2) traffic conditions. As discussed in *Appendix E: Scenario Development*, the team used recorded track data and the Surface Operations Data Analysis and Adaptation (SODAA) tool (ref. 43) to generate historical heuristics for various parameters, as input constraints into the Matlab program to generate the scenario files. Some heuristics-based parameters include: weight class distribution per run period; spots used by arrivals, departures, and aircraft type; runway usage by weight class; runway occupancy times; time for gate pushback and cleared gate; gate turnaround time; aircraft type percentage distribution per duration; airlines and gate usage; and departure fix used and runway assignment characteristics.

The Matlab tool takes as input the set of heuristics described above, as well as the following five parameters to generate the simulated scenarios. For each scenario, the user can specify the number of departures, the number of arrivals, departure loading profile, arrival loading profile, and duration of simulation time. The departure and arrival loading profile is used to specify the “bunching” of aircraft demand within a certain time window of the simulation run. For example, the researcher may want to insert two arrival pushes or bank within the 45-minute-long session. And in that session, the researcher may want the first arrival bank to happen 15 minutes after start of simulation, and the other to occur 35 minutes after start time.

The Matlab-generated traffic scenario profile will include two ‘humps,’ one at 15 minutes and the other at 35 minutes. The file will also use the SODAA-generated heuristics to proportionally allocate the appropriate aircraft types using particular runways, spot, and gate usage. It will also proportionally allocate the mix of airlines to particular terminals.

Similarly, the researcher can define the departure demand profile and Matlab tool (using SODAA-generated heuristics) to generate the correspondent departure mix of traffic. Taken together, the arrival and departure profiles define the traffic scenario.

Furthermore, for each traffic condition (e.g., Normal 1) six identical files were generated, but the call signs of individual aircraft were changed (e.g., replaced AAL1234 with AAL5631) to minimize controller familiarization with repetitive traffic scenarios.

RESULTS AND FINDINGS

Results from the 2 weeks of data collection for the DFW tower simulation (April 2010) are presented in this section. System performance metrics such as the number of stops, delays, fuel consumption, and emissions are presented. Human factors metrics include workload, situation awareness, and usability.

Summary of Scenarios and Total Aircraft

The 56 simulation data runs used for analysis were conducted with one of two possible controller configurations. A configuration defines all runs staffed by the same participant at a particular position (ground or local). For example, table 5 shows Controller 1 working all runs at the ground position and is referred to as "Controller Configuration 1," while table 6 shows Controller 1 working all traffic while at the local position (Controller Configuration 2). Obviously, as Controller 1 is working ground, Controller 2 is working the complementary position.

Tables 5 and 6 summarize these runs, with each run being one out of four traffic scenarios. See *Test Conditions and Matrix* for more details. It should be noted that the Baseline 2 advisory was tested only on the heavy scenarios. Further, the data for the second timeline run for the Heavy 2 scenario on Day 8, Run 1, was corrupted. Hence, throughout this section the fields for that particular run are left empty.

Along with the traffic level and advisory configuration, tables 5 and 6 also describe the total aircraft in each simulation run, and their split into arrivals and departures. The number of "complete" arrivals and departures are also listed, denoting the aircraft that used the runways and terminals on the east side, and whose trajectory was completed within the simulation time. Thus, complete arrivals are the ones that landed on either runways 17L or 17C and got to their gates within simulation time. Similarly, complete departures are the aircraft that pushed back and took off from runway 17R within simulation time. The sum of the "Total Complete Departure" and "Total Complete Arrivals" equals "Total Complete Aircraft." For the rest of this section, all analysis is conducted on such complete aircraft trajectories alone.

Highlights

The number of complete arrivals and departures indicates no change in throughput between the advisory and non-advisory runs.

TABLE 5: SUMMARY OF SIMULATIONS RUNS (CONTROLLER CONFIGURATION 1)

Scenario	Advisory	Day and Run	Total Aircraft	Total Complete Aircraft	Total Departures	Total Complete Departures	Total Arrivals	Total Complete Arrivals
Heavy 1	B1	Day1-Run3	133	77	68	42	65	35
	B1	Day9-Run4	133	80	68	45	65	35
	B2	Day6-Run2	133	81	68	44	65	37
	B2	Day7-Run3	133	84	68	48	65	36
	D	Day4-Run6	133	78	68	44	65	34
	D	Day6-Run6	133	76	68	43	65	33
	T	Day2-Run5	133	76	68	41	65	35
	T	Day5-Run1	133	80	68	44	65	36
Heavy 2	B1	Day3-Run4	134	78	69	44	65	34
	B1	Day5-Run5	134	78	69	46	65	32
	B2	Day8-Run5	134	78	69	45	65	33
	B2	Day9-Run2	134	76	69	43	65	33
	D	Day10-Run2	134	74	69	42	65	32
	D	Day2-Run1	134	75	69	41	65	34
	T	Day4-Run2	134	76	69	43	65	33
	T	Day8-Run1	-	-	-	-	-	-
Normal 1	B1	Day4-Run4	89	58	45	32	44	26
	B1	Day8-Run3	89	58	45	32	44	26
	D	Day1-Run1	89	54	45	32	44	22
	D	Day5-Run3	89	55	45	28	44	27
	T	Day3-Run2	89	59	45	33	44	26
	T	Day7-Run2	89	56	45	32	44	24
Normal 2	B1	Day2-Run3	89	56	45	28	44	28
	B1	Day6-Run4	89	57	45	28	44	29
	D	Day3-Run6	89	53	45	28	44	25
	D	Day7-Run5	89	56	45	28	44	28
	T	Day1-Run5	89	54	45	28	44	26
	T	Day9-Run6	89	55	45	28	44	27

TABLE 6: SUMMARY OF SIMULATIONS RUNS (CONTROLLER CONFIGURATION 2)

Scenario	Advisory	Day and Run	Total Aircraft	Total Complete Aircraft	Total Departures	Total Complete Departures	Total Arrivals	Total Complete Arrivals
Heavy 1	B1	Day2-Run6	133	80	68	45	65	35
	B1	Day5-Run2	133	79	68	45	65	34
	B2	Day6-Run1	133	80	68	43	65	37
	B2	Day7-Run4	133	77	68	44	65	33
	D	Day3-Run3	133	77	68	41	65	36
	D	Day8-Run2	133	79	68	42	65	37
	T	Day4-Run5	133	77	68	41	65	36
	T	Day9-Run3	133	79	68	44	65	35
Heavy 2	B1	Day10-Run1	134	76	69	43	65	33
	B1	Day4-Run1	134	77	69	45	65	32
	B2	Day8-Run6	134	74	69	43	65	31
	B2	Day9-Run1	134	75	69	43	65	32
	D	Day1-Run4	134	74	69	41	65	33
	D	Day5-Run6	134	73	69	42	65	31
	T	Day2-Run2	134	75	69	41	65	34
	T	Day6-Run5	134	75	69	43	65	32
Normal 1	B1	Day3-Run1	89	57	45	32	44	25
	B1	Day7-Run1	89	55	45	32	44	23
	D	Day2-Run4	89	55	45	33	44	22
	D	Day9-Run5	89	57	45	32	44	25
	T	Day1-Run2	89	55	45	32	44	23
	T	Day8-Run4	89	57	45	32	44	25
Normal 2	B1	Day1-Run6	89	55	45	28	44	27
	B1	Day7-Run6	89	54	45	28	44	26
	D	Day4-Run3	89	55	45	28	44	27
	D	Day6-Run3	89	56	45	28	44	28
	T	Day3-Run5	89	56	45	28	44	28
	T	Day2-Run6	133	80	68	45	65	35

Number of Stops

This section details the total departure and arrival stops, including ramp area, taxiway, and departure queue. Note that only the aircraft departing from runway 17R are considered, and out of those, only the aircraft with "complete" trajectories were considered. Tables 7 and 8 summarize the average stop-and-go situations for the two controller configurations, for all traffic level and advisory conditions.

In both the Heavy 1 and Heavy 2 scenarios, there is a decrease in the total number of departure stops with the use of the advisory, both timeline and datatag. The "simulated" advisory, tagged as Baseline 2 (B2) also shows a decrease in total stop-and-go situations, almost the same as the timeline and datatag case. The decrease is non-trivial, with an average reduction of about three stops. However, there is little change in number of stop-and-go situations in the Normal 1 and Normal 2 scenario in the Baseline 1 (B1) and advisory cases (Datatag–D and Timeline–T). A potential reason could be lower traffic in the normal scenarios; lower traffic density would probably result in fewer stop-and-go-inducing congested situations, with little scope for improvement through advisories.

In the advisory runs for the heavy scenario, there is a small increase in the number of departure stops in the ramp area. However, there is little change in the number of stops for the normal scenarios between the baseline and advisory cases. Note that the simulation design did not include any tool for effectively managing the ramp area; the advisories were provided only to the ground controller and local controller for spot release and departure runway usage, respectively. With the use of SRP in the absence of ramp management, it is possible that the number of stops could have increased drastically with the use of advisory.

Tables 7 and 8 also show the departure stops on the taxiways for the different simulation runs of the four scenarios. Taxiway here implies the part of the aircraft trajectory from spot release to the entry into the queue area. As is evident from the tables, analysis indicates that in all cases, 97 percent or more aircraft had no stops on the taxiways. One possible reason is the exclusion of the bridge traffic from the analysis; given the grid-like geometry of DFW's taxiways, there are only a few nodes where potential conflicts can arise due to merging traffic streams, and the nodes where traffic from the west side of DFW merges with the east side is one such possibility. In this analysis, stops for aircraft from the west side are not included. Further, with the emphasis on operations for the east-side terminals, it is possible that controllers resolved conflicts at such merge points by prioritizing east-side aircraft, and thus most of the taxiway stops were in the west-side aircraft that are not accounted for here.

The reduction of stop situations on the taxiways and departure queues was one of the motivations for the algorithms implemented in the experiment, and hence it is important to analyze the number of stops and total time stopped in the departure queue. Tables 7 and 8 also show the average departure queue stops in each scenario for the different runs with various advisory settings. There is a consistent reduction in the number of stops in the departure queue for the two heavy scenarios, with an average reduction of about 50 percent (from 5.8 stops in baseline 1 to 1.8 in advisory). However, the use of the advisory results in almost no change in the departure queue stops for the two normal scenarios.

With the use of the RS on the departure runway and the SRP on spots, it becomes necessary to analyze the stops for the arrivals, primarily for two reasons: 1) with the emphasis on reducing stops for departures, it is possible that controllers might be prioritizing departures over arrivals for the usage of the taxiways close to spots (this would be reflected in increased stops for the arrival aircraft in the advisory cases); and 2) with the use of RS, it is possible that the scheduler might be prioritizing departures over arrivals in scheduling runway usage (this would be indicated in the increase in number of stops for arrivals before crossing with the use of the advisory). As can be seen in tables 7 and 8 ("Avg Arr Taxiway Stops"), there is very little variation in the number of stops for the arrivals between the baseline and advisory case. Note that the results include only the stops before crossing runway 17R, and on the taxiway area before entering the spots. A fraction of the aircraft landed on runway 17L and had to cross runway 17C before coming to runway 17R, and the stops before crossing runway 17C are not included here for consistent comparison between all aircraft. This result, coupled with the little variation in number of stops before crossing runway 17R and on the taxiway, shows that the advisories had almost no effect on the number of stop-and-go situations for arrival aircraft.

Highlights

In the heavy scenario, the use of advisories results in an average decrease in total departure stops by three stops per departure. The advisory has little effect on departure stops in the normal scenario.

The advisory has little effect on arrival stops in both heavy and normal scenarios.

As compared to baseline 1, the use of advisories reduces the number of departure queue stops in the heavy scenario. The average number of departure stops in baseline 1 was 5.8, whereas in datatag and timeline runs it was 1.8.

TABLE 7: AVERAGE STOPS FOR DEPARTURES AND ARRIVALS
(CONTROLLER CONFIGURATION 1)

		Avg Total Dep Stops	Avg Dep Ramp Stops	Avg Dep Taxiway Stops	Avg Dep Runway Queue stops	Avg Total Arr Stops	Avg 17R Crossing Stops	Avg Arr Taxiway Stops
Heavy 1	B1	10.19	2.64	0.14	7.40	2.37	1.31	1.06
	B1	8.02	2.78	0.02	5.22	2.26	1.49	0.77
	B2	6.27	4.16	0.02	2.09	2.14	1.30	0.84
	B2	5.85	4.13	0.06	1.67	2.00	1.19	0.81
	D	5.48	3.59	0.07	1.82	2.32	1.68	0.65
	D	5.77	3.53	0.05	2.19	2.12	1.18	0.94
	T	5.73	4.02	0.00	1.71	1.91	1.11	0.80
	T	5.34	3.50	0.02	1.82	2.08	1.31	0.78
Heavy 2	B1	7.16	2.75	0.00	4.41	1.85	1.41	0.44
	B1	8.17	2.72	0.04	5.41	2.31	1.69	0.63
	B2	5.40	3.87	0.00	1.53	2.15	1.58	0.58
	B2	5.95	4.33	0.02	1.60	2.15	1.48	0.67
	D	5.61	3.93	0.00	1.68	1.85	1.18	0.68
	D	5.31	3.57	0.02	1.71	1.72	1.22	0.50
	T	5.02	3.56	0.05	1.42	2.12	1.33	0.79
	T	-	-	-	-	-	-	-
Normal 1	B1	3.47	2.56	0.00	0.91	1.65	0.96	0.69
	B1	3.34	2.69	0.00	0.66	1.35	0.77	0.58
	D	3.56	2.69	0.00	0.88	1.86	1.14	0.73
	D	3.21	2.46	0.04	0.71	1.07	0.67	0.41
	T	3.82	2.85	0.00	0.97	1.12	0.69	0.42
	T	3.63	2.75	0.00	0.88	1.21	0.67	0.54
Normal 2	B1	3.43	2.79	0.11	0.54	1.54	0.75	0.79
	B1	3.07	2.46	0.04	0.57	1.48	0.83	0.66
	D	3.21	2.54	0.00	0.68	1.08	0.56	0.52
	D	3.00	2.43	0.00	0.57	1.21	0.68	0.54
	T	3.39	2.75	0.00	0.64	1.69	0.96	0.73
	T	3.11	2.36	0.04	0.71	1.44	0.89	0.56

TABLE 8: AVERAGE STOPS FOR DEPARTURES AND ARRIVALS
(CONTROLLER CONFIGURATION 2)

		Avg Total Dep Stops	Avg Dep Ramp Stops	Avg Dep Taxiway Stops	Avg Dep Runway Queue stops	Avg Total Arr Stops	Avg 17R Crossing Stops	Avg Arr Taxiway Stops
Heavy 1	B1	8.80	2.80	0.02	5.98	2.06	1.23	0.83
	B1	8.49	3.04	0.02	5.42	2.38	1.38	1.00
	B2	5.86	4.07	0.00	1.79	1.92	1.27	0.65
	B2	5.43	3.64	0.02	1.77	2.27	1.39	0.88
	D	5.73	4.02	0.02	1.68	2.14	1.22	0.92
	D	5.71	3.64	0.05	2.02	1.89	1.05	0.84
	T	6.34	3.90	0.00	2.44	2.25	1.44	0.81
	T	5.30	3.68	0.05	1.57	2.03	1.20	0.83
Heavy 2	B1	8.89	3.16	0.13	5.60	2.53	1.75	0.78
	B1	9.21	2.98	0.05	6.19	2.55	1.73	0.82
	B2	5.16	3.86	0.00	1.30	2.32	1.58	0.74
	B2	5.26	4.33	0.02	0.91	2.31	1.66	0.66
	D	5.59	4.07	0.05	1.46	1.91	1.15	0.76
	D	5.48	3.79	0.05	1.64	2.35	1.58	0.77
	T	5.76	3.95	0.00	1.80	2.06	1.18	0.88
	T	6.35	4.40	0.07	1.88	2.06	1.31	0.75
Normal 1	B1	3.88	2.81	0.03	1.03	1.80	1.08	0.72
	B1	4.06	2.94	0.00	1.13	1.39	0.74	0.65
	D	3.67	2.76	0.06	0.85	1.55	0.86	0.68
	D	3.59	2.84	0.00	0.75	1.68	0.96	0.72
	T	4.16	2.94	0.03	1.19	1.74	1.04	0.70
	T	3.75	2.75	0.03	0.97	1.20	0.76	0.44
Normal 2	B1	3.14	2.36	0.04	0.75	1.52	0.81	0.70
	B1	3.25	2.68	0.00	0.57	1.12	0.65	0.46
	D	3.18	2.61	0.04	0.54	1.30	0.67	0.63
	D	2.89	2.50	0.04	0.36	1.39	0.86	0.54
	T	3.21	2.43	0.00	0.79	1.21	0.61	0.61
	T	3.50	2.79	0.00	0.71	1.59	0.97	0.62

Delays

This section presents the delay in all the scenarios. As in evaluating the number of stop situations, delay was considered only for the aircraft with complete trajectories. Delay is defined as the difference between actual taxi time minus unimpeded taxi time (in seconds). Unimpeded taxi times were obtained in advance from simulated data using the Airspace Traffic Generator (ATG) tool (ref. 44). Total delay is evaluated, as well as the split of the delay (in ramp, taxiway, and runway queue for departures; crossing and taxiway for arrivals) is evaluated. Further, movement area (defined as the taxiway and the runway queue) delay is also evaluated.

Tables 9 and 10 show the average delay for departures and arrivals for the two controller configurations. These tables also show the split of the delay in the various zones ("Percentage in Ramp," "Percentage in Taxi," and "Percentage in Queue" for departures; "Percentage in Taxi" and "Percentage in 17R crossing" for arrivals). As expected, delay is more in the heavy scenarios as compared to the normal scenarios. There is no consistent change in delay between the baseline and advisory case for both arrivals and departures. However, even though the advisory and baseline runs have the same average departure delay, there is a consistent trend for a larger fraction of delay in the ramp area with the use of advisories. This results in a 66 percent average reduction in movement area departure delay as compared to baseline 1.

Highlights

Average movement area delay reduced by 66 percent in heavy scenarios with the use of advisories.

Advisories have little effect on arrival stops in both heavy and normal scenarios.

TABLE 9: AVERAGE DELAY FOR DEPARTURES AND ARRIVALS
(CONTROLLER CONFIGURATION 1)

		Avg Dep Delay (seconds)	Percentage in Ramp	Percentage in Taxi	Percentage in Queue	Avg Arr Delay (seconds)	Percentage in Taxi	Percentage in 17R Crossing	Avg Dep Movement Area Delay (seconds)
Heavy 1	B1	468.7	9%	2%	90%	130.0	33%	67%	428.4
	B1	442.4	10%	0%	90%	128.3	13%	87%	398.9
	B2	448.3	71%	0%	29%	104.0	26%	74%	131.3
	B2	442.1	74%	1%	25%	81.7	17%	83%	115.9
	D	402.1	68%	1%	31%	132.3	16%	84%	127.3
	D	422.5	65%	1%	34%	89.5	24%	76%	149.2
	T	438.4	68%	1%	32%	79.0	25%	75%	141.0
	T	381.2	64%	1%	35%	110.7	15%	85%	135.6
Heavy 2	B1	384.9	11%	1%	88%	96.0	13%	87%	343.2
	B1	426.7	9%	1%	90%	118.5	14%	86%	388.9
	B2	375.0	73%	0%	27%	92.7	18%	82%	101.9
	B2	452.6	75%	1%	24%	89.1	20%	80%	112.7
	D	436.1	70%	1%	29%	81.3	12%	88%	129.0
	D	487.4	70%	1%	29%	84.5	26%	74%	144.0
	T	410.4	70%	1%	29%	89.6	16%	84%	123.0
	T	-	-	-	-	-	-	-	-
Normal 1	B1	85.8	33%	1%	66%	57.8	19%	81%	57.6
	B1	72.4	43%	3%	54%	55.8	25%	75%	41.6
	D	91.9	45%	1%	53%	72.0	21%	79%	50.3
	D	67.1	48%	3%	48%	44.0	31%	69%	34.6
	T	105.7	41%	3%	55%	44.2	28%	72%	61.9
	T	88.4	56%	2%	43%	52.8	28%	72%	39.3
Normal 2	B1	73.3	57%	8%	36%	44.3	37%	63%	31.6
	B1	53.8	38%	3%	59%	39.1	24%	76%	33.2
	D	71.2	44%	4%	53%	28.8	57%	43%	40.1
	D	56.0	55%	2%	43%	42.9	34%	66%	25.2
	T	76.3	50%	5%	45%	46.3	33%	67%	38.1
	T	59.5	42%	2%	57%	37.9	11%	89%	34.6

TABLE 10: AVERAGE DELAY FOR DEPARTURES AND ARRIVALS (CONTROLLER CONFIGURATION 2)

		Avg Dep Delay (seconds)	**Percentage in Ramp**	**Percentage in Taxi**	**Percentage in Queue**	**Avg Arr Delay (seconds)**	**Percentage in Taxi**	**Percentage in 17R Crossing**	**Avg Dep Movement Area Delay (seconds)**
Heavy 1	B1	419.2	9%	2%	90%	99.8	32%	68%	383.2
	B1	441.8	11%	0%	88%	103.4	28%	72%	392.0
	B2	446.3	66%	0%	34%	90.0	21%	79%	151.7
	B2	421.0	63%	1%	36%	94.8	22%	78%	155.9
	D	453.2	65%	1%	34%	100.3	29%	71%	158.1
	D	410.7	64%	1%	35%	101.7	19%	81%	149.7
	T	482.4	66%	1%	33%	110.7	22%	78%	166.3
	T	413.4	72%	1%	27%	120.5	28%	72%	113.8
Heavy 2	B1	424.5	12%	1%	87%	166.5	11%	89%	374.8
	B1	408.2	14%	2%	84%	140.3	13%	87%	350.3
	B2	385.6	71%	0%	29%	123.0	23%	77%	113.1
	B2	443.5	86%	1%	13%	105.8	15%	85%	61.4
	D	449.6	68%	1%	30%	74.8	28%	72%	141.9
	D	398.6	71%	1%	28%	129.4	16%	84%	114.2
	T	435.9	69%	1%	31%	79.7	29%	71%	136.9
	T	453.5	75%	1%	23%	84.9	23%	77%	112.0
Normal 1	B1	102.8	39%	1%	60%	69.1	40%	60%	62.9
	B1	120.1	39%	1%	60%	57.7	35%	65%	73.0
	D	95.8	41%	11%	48%	56.0	22%	78%	56.2
	D	94.5	52%	0%	47%	74.6	38%	62%	45.1
	T	102.2	42%	3%	55%	70.3	32%	68%	59.4
	T	113.1	43%	1%	56%	55.2	23%	77%	64.6
Normal 2	B1	61.7	37%	6%	56%	52.1	36%	64%	38.6
	B1	60.2	50%	3%	47%	31.7	30%	70%	30.3
	D	66.3	47%	6%	47%	43.7	40%	60%	35.3
	D	60.4	56%	14%	31%	50.0	29%	71%	26.9
	T	60.9	43%	2%	54%	36.2	49%	51%	34.5
	T	78.0	56%	4%	40%	48.1	31%	69%	34.6

Fuel Consumption

This section presents the total fuel consumption in all the scenarios. As in evaluating the number of stop situations, the fuel consumption was considered only for the aircraft with complete trajectories. The method used for calculating fuel consumption is detailed in reference 16.

Tables 11 and 12 present the average total fuel consumption for both arrivals and departures, along with the split into pertinent operations. The fuel consumption for arrivals in ramp operations was not considered because the movement of the arrivals in the ramp area was an automated process. There is not much difference in the total fuel consumption for both arrivals and departures in the advisory and non-advisory case. The fuel consumption in departures is definitely higher in the heavier scenarios. The results show that in the heavier scenarios, the use of advisories shifts the fuel consumption from the departure queue to the ramp area. The SARDA simulation did not incorporate the SRP-LT concept and a ramp control mechanism, which could potentially reduce the fuel consumption in heavy scenarios by about 45 percent ("Percentage in Ramp" under heavy scenarios). Further, there is a 37.7 percent average decrease in the departure movement area fuel consumption in the heavy scenarios.

Highlights

SARDA advisories result in a 37.7 percent decrease in departure movement area fuel consumption compared to baseline 1.

Average total departure fuel consumption could have been reduced by 45 percent with the use of SARDA concept, if SRP-LT and ramp control had been used.

The SARDA concept has no measured effect on arrival fuel consumption in the movement area.

TABLE 11: AVERAGE FUEL CONSUMPTION AND SPLIT FOR DEPARTURES AND ARRIVALS (CONTROLLER CONFIGURATION 1)

		Avg Total Dep Fuel (kg)	Percentage in Ramp	Percentage in Taxi	Percentage in Queue	Avg Total Arr Fuel (kg)	Percentage in Crossing 17R	Percentage in Taxi	Avg Dep Movement Area Fuel (kg)
Heavy 1	B1	223.43	14%	26%	61%	92.59	41%	59%	192.46
	B1	209.41	14%	25%	60%	93.25	46%	54%	179.34
	B2	212.39	48%	26%	26%	84.82	40%	60%	109.89
	B2	208.89	50%	26%	24%	80.83	40%	60%	104.68
	D	193.76	44%	28%	29%	93.45	47%	53%	109.23
	D	210.05	43%	26%	31%	81.87	41%	59%	119.24
	T	204.19	46%	25%	29%	79.19	39%	61%	111.15
	T	199.95	43%	27%	31%	86.49	45%	55%	114.87
Heavy 2	B1	177.63	15%	26%	58%	79.57	43%	57%	150.15
	B1	186.43	14%	25%	61%	87.56	46%	54%	160.62
	B2	163.48	45%	28%	27%	79.54	42%	58%	90.49
	B2	187.94	49%	25%	25%	77.82	39%	61%	95.39
	D	172.41	45%	26%	29%	76.38	40%	60%	95.01
	D	191.99	44%	24%	32%	78.26	38%	62%	106.91
	T	179.38	43%	26%	30%	78.70	40%	60%	101.43
	T	-	-	-	-	-	-	-	-
Normal 1	B1	95.62	22%	46%	31%	69.63	38%	62%	74.48
	B1	94.48	24%	47%	29%	67.37	36%	64%	71.71
	D	98.10	25%	46%	29%	71.42	39%	61%	73.43
	D	97.50	24%	47%	28%	63.96	30%	70%	73.64
	T	100.95	24%	44%	31%	67.98	34%	66%	76.60
	T	96.96	26%	46%	28%	69.48	35%	65%	71.94
Normal 2	B1	101.12	27%	48%	26%	64.61	30%	70%	74.19
	B1	95.45	23%	48%	29%	62.78	32%	68%	73.39
	D	100.52	26%	46%	28%	62.42	25%	75%	74.53
	D	96.24	26%	47%	27%	61.43	30%	70%	71.67
	T	98.96	25%	48%	27%	63.93	31%	69%	73.87
	T	97.88	25%	46%	28%	59.47	33%	67%	73.30

TABLE 12: AVERAGE FUEL CONSUMPTION AND SPLIT FOR DEPARTURES AND ARRIVALS (CONTROLLER CONFIGURATION 2)

		Avg Total Dep Fuel (kg)	Percentage in Ramp	Percentage in Taxi	Percentage in Queue	Avg Total Arr Fuel (kg)	Percentage in Crossing 17R	Percentage in Taxi	Avg Dep Movement Area Fuel (kg)
Heavy 1	B1	200.46	14%	27%	59%	87.80	39%	61%	172.09
	B1	211.45	15%	26%	60%	89.29	39%	61%	179.82
	B2	209.51	45%	26%	29%	83.21	40%	60%	114.57
	B2	197.89	43%	27%	30%	90.11	41%	59%	112.41
	D	221.64	46%	25%	29%	89.33	39%	61%	119.44
	D	199.36	43%	27%	31%	86.62	40%	60%	114.20
	T	223.68	46%	25%	29%	89.37	42%	58%	121.05
	T	199.53	47%	27%	26%	93.13	41%	59%	104.97
Heavy 2	B1	187.60	15%	25%	60%	98.18	49%	51%	158.60
	B1	187.92	17%	25%	58%	92.76	47%	53%	156.36
	B2	165.79	44%	27%	29%	87.87	41%	59%	93.06
	B2	188.93	55%	25%	20%	81.13	43%	57%	85.78
	D	181.81	44%	25%	30%	74.27	37%	63%	101.55
	D	173.21	45%	26%	29%	89.68	45%	55%	95.84
	T	176.52	43%	25%	31%	77.37	35%	65%	99.89
	T	187.46	48%	25%	27%	79.79	38%	62%	96.78
Normal 1	B1	99.73	24%	44%	32%	75.37	35%	65%	76.13
	B1	106.07	26%	42%	32%	72.06	35%	65%	78.59
	D	99.19	25%	47%	29%	65.92	36%	64%	74.84
	D	100.88	28%	44%	28%	73.74	34%	66%	72.77
	T	103.23	26%	44%	30%	68.38	37%	63%	76.05
	T	101.45	25%	44%	32%	67.83	37%	63%	76.40
Normal 2	B1	97.45	22%	48%	30%	64.58	32%	68%	75.83
	B1	97.68	25%	47%	28%	61.53	29%	71%	73.42
	D	99.32	25%	47%	28%	62.94	29%	71%	74.59
	D	97.96	26%	49%	25%	64.19	31%	69%	72.50
	T	96.85	23%	47%	29%	60.56	27%	73%	74.15
	T	101.55	26%	46%	28%	64.29	32%	68%	75.09

Emissions

This section presents the total emissions in all the scenarios. As in evaluating the number of stop situations, emissions were considered only for the aircraft with complete trajectories. The methodology is described in reference 16. Three types of emissions are evaluated: hydrocarbons (HC), carbon monoxide (CO), and nitrogen oxides (NO_x).

Tables 13 and 14 show the average hydrocarbon emissions for all the scenarios for controller configurations 1 and 2, respectively. The emissions have been divided into arrivals and departures, and the split (in ramp, taxiway, and queue for departures; taxiway and crossings for arrivals) is also given. Similarly, tables 15 and 16 give the carbon monoxide emissions, while tables 17 and 18 give the nitrogen oxide emissions. The emissions are lower in the normal scenarios than the heavy scenarios, which are expected because aircraft spend more time on the surface in the heavy scenario and have higher fuel consumption, leading to more emissions. As in fuel consumption, there is a consistent trend for decrease in movement area emissions, with an average decrease of 38.8 percent in hydrocarbon emissions, 38.9 percent decrease in carbon monoxide emissions, and 37.8 percent decrease in nitrogen oxides. Again, the use of advisories has little effect on the arrival emissions in the movement area.

Highlights

38.8 percent decrease in movement area departure hydrocarbon emissions.

38.9 percent decrease in movement area departure carbon monoxide emissions.

37.8 percent decrease in movement area departure nitrogen oxide emissions.

The SARDA concept has no measured effect on arrival emissions in the movement area.

TABLE 13: AVERAGE HYDROCARBON EMISSIONS AND SPLIT FOR DEPARTURES AND ARRIVALS (CONTROLLER CONFIGURATION 1)

		Avg Total Dep HC (gm)	Percentage in Ramp	Percentage in Taxi	Percentage in Queue	Avg Total Arr HC (gm)	Percentage in Crossing 17R	Percentage in Taxi	Avg Dep Movement Area HC (gm)
Heavy 1	B1	698.3	12%	26%	62%	290.6	61%	39%	611.3
	B1	627.0	13%	26%	61%	284.0	57%	43%	544.5
	B2	648.8	49%	26%	26%	263.9	59%	41%	334.1
	B2	650.6	50%	25%	24%	242.9	63%	37%	322.1
	D	592.8	44%	27%	29%	288.8	55%	45%	330.4
	D	664.6	44%	26%	30%	238.3	62%	38%	372.6
	T	616.4	45%	24%	31%	246.5	61%	39%	339.2
	T	642.5	43%	27%	30%	265.8	55%	45%	365.0
Heavy 2	B1	581.1	15%	26%	59%	198.1	57%	43%	493.8
	B1	600.4	13%	24%	62%	214.8	55%	45%	519.7
	B2	524.9	45%	27%	27%	195.3	56%	44%	286.8
	B2	614.0	49%	24%	26%	196.5	60%	40%	312.6
	D	553.3	46%	25%	29%	191.1	61%	39%	299.6
	D	622.2	45%	23%	33%	198.3	61%	39%	343.0
	T	592.0	45%	25%	30%	205.9	58%	42%	326.2
	T	-	-	-	-	-	-	-	-
Normal 1	B1	266.7	22%	45%	33%	190.6	63%	37%	207.2
	B1	262.4	25%	45%	30%	194.8	62%	38%	197.4
	D	275.4	26%	44%	30%	183.3	60%	40%	203.7
	D	320.1	23%	49%	28%	190.6	71%	29%	245.1
	T	281.1	25%	43%	32%	195.0	66%	34%	210.8
	T	267.6	27%	45%	28%	199.3	63%	37%	194.3
Normal 2	B1	329.8	25%	49%	26%	194.7	69%	31%	246.4
	B1	312.4	22%	49%	29%	188.9	68%	32%	244.2
	D	330.7	25%	47%	29%	186.1	75%	25%	249.6
	D	316.7	24%	48%	28%	184.5	70%	30%	239.5
	T	325.3	24%	49%	27%	190.0	70%	30%	245.9
	T	322.2	24%	47%	29%	177.7	67%	33%	243.9

TABLE 14: AVERAGE HYDROCARBON EMISSIONS AND SPLIT FOR DEPARTURES AND ARRIVALS (CONTROLLER CONFIGURATION 2)

		Avg Total Dep HC (gm)	Percentage in Ramp	Percentage in Taxi	Percentage in Queue	Avg Total Arr HC (gm)	Percentage in Crossing 17R	Percentage in Taxi	Avg Dep Movement Area HC (gm)
Heavy 1	B1	664.4	13%	26%	61%	265.6	62%	38%	580.8
	B1	667.8	14%	25%	61%	288.1	60%	40%	576.1
	B2	671.4	45%	26%	29%	263.8	59%	41%	366.1
	B2	622.3	44%	26%	30%	282.1	59%	41%	346.9
	D	731.4	48%	24%	28%	282.3	62%	38%	382.3
	D	628.3	41%	27%	32%	273.2	59%	41%	368.8
	T	732.6	47%	24%	28%	285.9	58%	42%	384.8
	T	630.3	48%	27%	25%	295.0	59%	41%	330.4
Heavy 2	B1	595.9	15%	25%	60%	236.0	51%	49%	506.2
	B1	608.6	16%	24%	60%	220.3	54%	46%	511.6
	B2	530.3	44%	26%	30%	224.9	57%	43%	297.1
	B2	613.5	55%	24%	21%	191.3	57%	43%	277.7
	D	580.0	45%	25%	30%	192.2	64%	36%	317.1
	D	570.1	46%	25%	29%	226.8	54%	46%	309.0
	T	565.4	44%	25%	31%	197.8	64%	36%	317.1
	T	614.4	50%	24%	26%	195.8	63%	37%	310.2
Normal 1	B1	279.0	24%	42%	34%	214.9	66%	34%	212.1
	B1	296.6	27%	40%	33%	204.2	64%	36%	217.8
	D	277.8	25%	46%	29%	170.6	62%	38%	207.0
	D	278.0	28%	43%	29%	215.4	64%	36%	199.7
	T	285.0	26%	42%	31%	175.1	63%	37%	210.1
	T	284.9	25%	42%	33%	189.2	63%	37%	213.0
Normal 2	B1	320.0	21%	49%	30%	190.5	68%	32%	252.9
	B1	318.5	23%	48%	28%	180.0	73%	27%	243.8
	D	326.4	24%	48%	28%	188.3	72%	28%	248.7
	D	321.7	25%	50%	25%	194.3	69%	31%	240.9
	T	318.3	23%	49%	29%	179.6	73%	27%	246.2
	T	334.4	25%	47%	28%	194.7	68%	32%	250.3

TABLE 15: AVERAGE CARBON MONOXIDE EMISSIONS AND SPLIT FOR DEPARTURES AND ARRIVALS (CONTROLLER CONFIGURATION 1)

		Avg Total Dep CO (gm)	Percentage in Ramp	Percentage in Taxi	Percentage in Queue	Avg Total Arr CO (gm)	Percentage in Crossing 17R	Percentage in Taxi	Avg Dep Movement Area CO (gm)
Heavy 1	B1	17503.0	13%	26%	62%	7459.3	60%	40%	15294.4
	B1	16790.7	15%	26%	59%	7383.5	53%	47%	14291.0
	B2	16675.1	47%	26%	27%	6859.1	58%	42%	8817.4
	B2	16445.5	48%	26%	25%	6256.3	59%	41%	8485.2
	D	15675.8	46%	27%	27%	7374.8	52%	48%	8530.1
	D	16095.2	44%	27%	29%	6310.2	61%	39%	9084.1
	T	16320.8	45%	26%	29%	6276.3	61%	39%	8902.5
	T	15855.6	44%	28%	28%	6842.5	54%	46%	8892.8
Heavy 2	B1	15913.3	14%	26%	59%	6496.5	57%	43%	13607.0
	B1	16815.7	14%	25%	62%	6988.3	55%	45%	14542.0
	B2	16045.2	48%	27%	25%	6308.5	57%	43%	8394.8
	B2	17532.4	51%	24%	24%	6501.7	60%	40%	8531.1
	D	17095.0	49%	24%	27%	6346.4	59%	41%	8737.3
	D	18061.0	51%	23%	26%	6373.8	62%	38%	8867.1
	T	16307.4	48%	26%	26%	6664.8	59%	41%	8406.4
	T	-	-	-	-	-	-	-	-
Normal 1	B1	9503.7	22%	45%	33%	5228.9	60%	40%	7391.6
	B1	9348.3	25%	45%	30%	5188.5	61%	39%	7036.0
	D	9814.9	26%	44%	30%	5431.3	58%	42%	7264.1
	D	9387.2	24%	47%	29%	6081.0	69%	31%	7139.0
	T	10021.4	25%	43%	32%	5058.7	65%	35%	7518.3
	T	9533.7	27%	45%	28%	5177.3	62%	38%	6925.2
Normal 2	B1	9806.4	26%	46%	27%	6113.0	70%	30%	7214.8
	B1	9178.3	23%	48%	29%	5855.6	69%	31%	7095.0
	D	9715.4	26%	45%	29%	5793.7	76%	24%	7213.2
	D	9211.7	25%	47%	27%	5926.7	68%	32%	6867.4
	T	9593.0	25%	47%	28%	6072.5	68%	32%	7196.7
	T	9447.7	25%	46%	29%	5665.7	65%	35%	7109.2

TABLE 16: AVERAGE CARBON MONOXIDE EMISSIONS AND SPLIT FOR DEPARTURES AND ARRIVALS (CONTROLLER CONFIGURATION 2)

		Avg Total Dep CO (gm)	Percentage in Ramp	Percentage in Taxi	Percentage in Queue	Avg Total Arr CO (gm)	Percentage in Crossing 17R	Percentage in Taxi	Avg Dep Movement Area CO (gm)
Heavy 1	B1	17041.8	14%	26%	61%	6758.6	62%	38%	14730.2
	B1	16858.4	15%	25%	60%	7237.6	60%	40%	14342.9
	B2	17074.2	45%	26%	29%	6651.7	58%	42%	9408.8
	B2	16344.4	43%	26%	31%	6833.3	60%	40%	9353.4
	D	17314.9	45%	26%	29%	7097.4	62%	38%	9450.9
	D	16035.4	42%	27%	31%	7106.8	57%	43%	9282.4
	T	17692.0	46%	25%	29%	7273.1	57%	43%	9619.1
	T	16101.8	47%	27%	26%	7318.6	59%	41%	8474.0
Heavy 2	B1	16899.8	15%	25%	60%	7987.9	49%	51%	14344.7
	B1	16912.1	16%	25%	59%	7340.8	52%	48%	14197.2
	B2	16036.1	46%	26%	28%	7314.3	56%	44%	8607.4
	B2	17565.9	57%	24%	19%	6832.5	56%	44%	7589.6
	D	17406.7	48%	24%	28%	6207.9	63%	37%	9063.8
	D	16381.5	48%	24%	28%	7344.5	54%	46%	8528.7
	T	17139.1	48%	24%	29%	6459.3	63%	37%	8993.4
	T	17577.6	51%	24%	25%	6461.0	62%	38%	8551.9
Normal 1	B1	9943.6	24%	42%	34%	5574.6	64%	36%	7567.0
	B1	10577.4	27%	40%	33%	5157.5	64%	36%	7770.3
	D	9898.2	25%	46%	29%	5172.4	61%	39%	7381.3
	D	9908.8	28%	43%	29%	5687.3	61%	39%	7121.4
	T	10153.1	26%	42%	31%	5572.2	62%	38%	7491.0
	T	10160.1	25%	42%	33%	5033.3	61%	39%	7598.3
Normal 2	B1	9346.0	22%	47%	31%	5985.7	68%	32%	7327.8
	B1	9493.1	25%	46%	29%	5642.0	71%	29%	7157.0
	D	9668.9	25%	46%	29%	5997.4	70%	30%	7269.4
	D	9445.4	26%	48%	27%	6270.7	67%	33%	7036.7
	T	9330.8	23%	46%	31%	5703.9	72%	28%	7215.2
	T	9777.7	26%	45%	29%	6200.1	67%	33%	7264.6

TABLE 17: AVERAGE NITROGEN OXIDE EMISSIONS AND SPLIT FOR DEPARTURES AND ARRIVALS (CONTROLLER CONFIGURATION 1)

		Avg Total Dep NOx (gm)	Percentage in Ramp	Percentage in Taxi	Percentage in Queue	Avg Total Arr NOx (gm)	Percentage in Crossing 17R	Percentage in Taxi	Avg Dep Movement Area NOx (gm)
Heavy 1	B1	1824.8	14%	25%	61%	748.9	59%	41%	1566.8
	B1	1674.6	15%	25%	60%	751.0	55%	45%	1431.5
	B2	1698.4	48%	26%	26%	685.2	60%	40%	883.4
	B2	1674.6	50%	26%	25%	653.0	61%	39%	842.6
	D	1544.4	43%	28%	29%	754.4	54%	46%	879.7
	D	1699.0	43%	25%	32%	657.8	59%	41%	972.4
	T	1623.7	45%	25%	30%	642.5	61%	39%	889.7
	T	1609.1	42%	27%	31%	698.1	55%	45%	931.0
Heavy 2	B1	1420.1	16%	26%	58%	615.7	57%	43%	1191.5
	B1	1487.5	14%	25%	61%	678.9	55%	45%	1274.7
	B2	1272.9	44%	28%	28%	618.9	58%	42%	712.0
	B2	1478.9	49%	25%	26%	603.0	61%	39%	760.6
	D	1337.4	44%	27%	29%	590.8	61%	39%	747.5
	D	1501.3	43%	24%	33%	608.6	62%	38%	852.1
	T	1419.0	43%	26%	31%	611.1	60%	40%	813.0
	T	-	-	-	-	-	-	-	-
Normal 1	B1	731.3	23%	46%	31%	557.3	63%	37%	565.6
	B1	723.0	25%	46%	29%	541.4	64%	36%	545.0
	D	749.9	26%	46%	29%	564.7	61%	39%	558.0
	D	774.8	25%	47%	28%	497.7	71%	29%	581.7
	T	771.8	25%	44%	31%	547.7	66%	34%	581.9
	T	742.0	26%	46%	28%	559.6	66%	34%	547.8
Normal 2	B1	801.9	27%	48%	25%	504.9	70%	30%	585.7
	B1	758.7	24%	48%	28%	491.9	68%	32%	579.7
	D	798.1	26%	46%	28%	488.5	74%	26%	589.2
	D	766.1	26%	47%	27%	477.1	70%	30%	568.1
	T	785.5	26%	48%	26%	497.9	70%	30%	582.8
	T	778.2	26%	46%	28%	463.3	68%	32%	579.6

TABLE 18: AVERAGE NITROGEN OXIDE EMISSIONS AND SPLIT FOR DEPARTURES AND ARRIVALS (CONTROLLER CONFIGURATION 2)

		Avg Total Dep NOx (gm)	Percentage in Ramp	Percentage in Taxi	Percentage in Queue	Avg Total Arr NOx (gm)	Percentage in Crossing 17R	Percentage in Taxi	Avg Dep Movement Area NOx (gm)
Heavy 1	B1	1630.0	14%	27%	59%	709.8	61%	39%	1394.7
	B1	1715.9	15%	25%	59%	725.6	61%	39%	1454.8
	B2	1676.0	45%	26%	29%	674.7	60%	40%	921.1
	B2	1575.8	43%	27%	30%	736.2	59%	41%	895.9
	D	1789.4	46%	25%	29%	723.7	61%	39%	964.2
	D	1595.3	42%	27%	31%	697.3	60%	40%	920.7
	T	1806.4	46%	25%	30%	722.9	58%	42%	980.5
	T	1599.4	47%	27%	26%	754.0	59%	41%	847.8
Heavy 2	B1	1497.3	16%	25%	60%	754.9	52%	48%	1259.6
	B1	1506.6	17%	25%	58%	716.8	53%	47%	1248.2
	B2	1292.3	43%	28%	29%	681.1	60%	40%	732.4
	B2	1484.3	54%	25%	21%	620.8	57%	43%	684.8
	D	1416.8	44%	26%	31%	578.9	63%	37%	800.2
	D	1371.1	44%	27%	29%	696.2	56%	44%	767.5
	T	1377.9	43%	26%	32%	601.1	65%	35%	791.4
	T	1475.6	48%	25%	27%	619.9	62%	38%	770.8
Normal 1	B1	762.9	24%	44%	32%	609.0	65%	35%	578.3
	B1	810.5	26%	42%	32%	583.3	65%	35%	596.8
	D	758.6	25%	47%	28%	518.2	64%	36%	568.8
	D	771.4	28%	44%	28%	592.9	66%	34%	553.0
	T	790.6	27%	43%	30%	534.8	64%	36%	578.7
	T	774.9	25%	43%	31%	543.5	63%	37%	580.2
Normal 2	B1	775.4	23%	48%	29%	505.0	68%	32%	599.7
	B1	773.9	25%	47%	28%	480.7	71%	29%	578.6
	D	787.7	25%	47%	28%	490.2	72%	28%	588.5
	D	777.7	26%	49%	25%	497.8	69%	31%	572.2
	T	770.2	24%	47%	29%	472.4	74%	26%	585.6
	T	808.3	27%	46%	27%	501.6	68%	32%	593.8

Human Factors Results

The findings on controller workload, objective and subjective situation awareness, and usability of the SARDA concept based on two variables (traffic load and advisory usage) are presented in this section. It should be noted that the results were gathered from just two test subjects, which may limit the generalization of the findings. Quantitative results were obtained from the post-run questionnaires administered to the controller participants and pseudo-pilots. These results, the statistical tests performed, and their inferences are summarized in tables 19–22, and figures 8 and 9.

Controller workload, subjective SA, and objective SA for ground and local controller positions were examined through separate Analysis of Variance (ANOVA) tests. For each position, a total of six ANOVAs were performed—3 (advisory modes) x 2 (traffic levels)—using three repeated measures. The advisory modes consisted of Baseline-1 (B1), Datatag, and Timeline, and the traffic levels were normal and high. In addition, three separate, repeated measures ANOVA tests examined four levels of advisories (B1, Datatag, Timeline, and B2) with results from the high-traffic condition only. Furthermore, the B1 condition was used as a baseline, against which a pair-wise comparison was made (i.e., B1 vs. Datatag, B1 vs. Timeline, B1 vs. B2). The results from the human factors analysis of the SARDA concept are presented in figures 8–10.

Pseudo-pilot (PP) workload was analyzed using a 3 (advisory modes: Baseline, Datatag, and Timeline) x 2 (traffic level: normal and high) repeated ANOVA tests. Pearson correlation coefficients were computed to assess the relationships among the performance metrics of workload, subjective SA, and objective SA. Analyses revealed a negative correlation between workload and subjective SA ($r = -0.777$, $n = 95$, $p < 0.001$), a positive correlation between subjective SA and objective SA ($r = 0.298$, $n = 95$, $p = 0.003$), and no significant correlation between workload and objective SA ($r = -0.176$, $n = 95$, $p = 0.089$). This analysis highlights the potential interdependencies among subjective self-assessment measures—in this case, perceived workload and perceived situational awareness. Individuals may be more likely to rate their situational awareness as low in instances when they perceive their workload as high. This analysis also provides support for including an objective measure of SA, which may reveal aspects of SA unbiased by perceived workload.

TABLE 19: ANOVA RESULTS EVALUATING EFFECT OF TRAFFIC ON WORKLOAD AT POSITIONS

Effect of Traffic on Workload				**Mean (Std. Err.)[2]**	
Position[1]	*Performance Metric*	*Statistical Test*	*Statistical Significance*	*Normal Traffic*	*High Traffic*
Ground	Workload	F(1,7)=133.25	p<.001	**.22 (.02)**	**.53 (.02)**
Local	Workload	F(1,7)=93.35	p<.001	**.24 (.02)**	**.54 (.02)**
PP1 (Ground Departure)	Workload	F(1,5)=8.01	p=.037	**.14 (.00)**	**.21 (.02)**
PP2 (Ground Departure)	Workload	F(1,5)=5.15	p=.072	.15 (.00)	.19 (.02)
PP3 (Ground Arrival)	Workload	F(1,5)=6.48	p=.052	.21 (.02)	.28 (.03)
PP4 (Ground Arrival)	Workload	F(1,5)=61.44	p=.001	**.26 (.02)**	**.47 (.02)**
PP5 (Local Departure)	Workload	F(1,5)=21.16	p=.006	**.21 (.01)**	**.27 (.02**
PP6 (Local Arrival)	Workload	F(1,5)=67.74	p<.001	**.33 (.03)**	**.50 (.02)**

[1] "PP" represents pseudo-pilot controlling traffic at designated position.

[2] Means highlighted in bold text are statistically different at p<.05. The workload scale ranges between 0.0 (low) and 1.0 (high).

TABLE 20: ANOVA RESULTS EVALUATING EFFECT OF TRAFFIC ON CONTROLLER SITUATION AWARENESS

Effect of Traffic on Situation Awareness				**Mean (Std. Err.)[1]**	
Position	*Performance Metric*	*Statistical Test*	*Statistical Significance*	*Normal Traffic*	*High Traffic*
Ground	Subjective SA	F(1,7)=170.45	p<.001	**.94 (.01)**	**.72 (.02)**
Local	Subjective SA	F(1,7)=29.31	p=.001	**.92 (.03)**	**.76 (.01)**
Ground	Objective SA	F(1,6)=3.79	p=.099	.84 (.04)	.70 (.06)
Local	Objective SA	F(1,7)=0.18	p=.681	.73 (.02)	.74 (.03)

[1] Means highlighted in bold text are statistically different at p<.05. The situation awareness scale ranges between 0.0 (low) and 1.0 (high).

TABLE 21: ANOVA RESULTS EVALUATING EFFECT OF ADVISORIES ON CONTROLLER WORKLOAD

Effect of Advisory on Workload				Mean (Std. Err.)[1]			
Position	*Performance Metric*	*Statistical Test*	*Statistical Significance*	*Base-line*	*Data-tag*	*Time-line*	*Spot metering*
Ground	Workload	F(2,14)=2.11	p=.159	.33 (.03)	.42 (.03)	.36 (.03)	
Ground	Workload (High Traffic)	F(3,21)=2.94	p=.057	**.45 (.05)**	.60 (.05)	.53 (.05)	**.67 (.05)**
Local	Workload	F(2,14)=1.57	p=.244	.44 (.04)	.36 (.03)	.38 (.03)	
Local	Workload (High Traffic)	F(3,21)=3.06	p=.050	**.60 (.05)**	.51 (.05)	.51 (.04)	**.40 (.05)**
PP1 (Gnd Dep)	Workload	F(2,10)=1.06	p=.383	.19 (.03)	.17 (.01)	.17 (.01)	
PP2 (Gnd Dep)	Workload	F(2,10)=3.07	p=.091	.15 (.00)	.16 (.01)	.20 (.03)	
PP3 (Gnd Arr)	Workload	F(2,10)=0.67	p=.534	.24 (.02)	.23 (.02)	.25 (.03)	
PP4 (Gnd Arr)	Workload	F(2,10)=1.32	p=.311	.34 (.02)	.37 (.03)	.39 (.02)	
PP5 (Lcl Dep)	Workload	F(2,10)=3.52	p=.070	**.27 (.03)**	.24 (.03)	**.21 (.01)**	
PP6 (Lcl Arr)	Workload	F(2,10)=0.17	p=.847	.42 (.01)	.42 (.03)	.40 (.05)	

[1]Means highlighted in bold text are statistically different from baseline based on planned comparisons using p<.05. The workload scale ranges between 0.0 (low) and 1.0 (high).

TABLE 22: ANOVA RESULTS EVALUATING EFFECT OF ADVISORIES ON CONTROLLER SITUATIONAL AWARENESS

Effect of Advisory on Situational Awareness				**Mean (Std. Err.)[1]**			
Position	*Performance Metric*	*Statistical Test*	*Statistical Significance*	*Base-line*	*Data-tag*	*Time-line*	*Spot metering*
Ground	Subjective SA	F(2,14)=19.67	p<.001	**.90 (.02)**	**.77 (.03)**	**.82 (.01)**	
Ground	Subjective SA (High Traffic)	F(3,21)=4.61	p=.013	**.81 (.03)**	**.63 (.05)**	**.71 (.02)**	**.68 (.02)**
Ground	Objective SA	F(2,12)=0.74	p=.500	.80 (.04)	.74 (.06)	.76 (.04)	
Ground	Objective SA x Traffic	F(2,12)=5.48	p=.020	N=.77 **H=.83**	N=.89 **H=.60**	N=.86 **H=.66**	
Ground	Objective SA (High Traffic)	F(3,18)=2.84	p=.067	**.83 (.07)**	**.60 (.09)**	**.66 (.06)**	.66 (.08)
Local	Subjective SA	F(2,14)=0.01	p=.989	.84 (.02)	.84 (.01)	.84 (.02)	
Local	Subjective SA (High Traffic)	F(3,21)=2.51	p=.086	.76 (.02)	.75 (.03)	.77 (.02)	.86 (.04)
Local	Objective SA	F(2,14)=0.58	p=.575	.76 (.03)	.74 (.02)	.71 (.03)	
Local	Objective SA (High Traffic)	F(3,21)=0.20	p=.894	.73 (.03)	.78 (.05)	.72 (.05)	.73 (.09)

[1]Means highlighted in bold text are statistically different from baseline based on planned comparisons using p<.05. The workload scale ranges between 0.0 (low) and 1.0 (high).

Workload

Results revealed that the high-traffic level increased self-reported perceived workload for both ground and local controllers, as anticipated. Compared to Baseline-1 in figure 8, the introduction of SARDA advisories imposed little impact on participants' self-reported perceived workload.

Ground Controller

Although one might expect the advisories to alleviate controllers' workload by offloading responsibility for spot release and runway usage decisions, the advisory conditions differed from the baseline in ways that may have counteracted this potential benefit. For example, the advisories' goal (metering traffic to the departure queue from the spot) differed from the historical objective of the ground controllers, which is to minimize aircraft wait time on the ramp. In post-study interviews, controllers indicated some disharmony between the SRP advice and their nominal operations, potentially contributing to an increase in perceived workload.

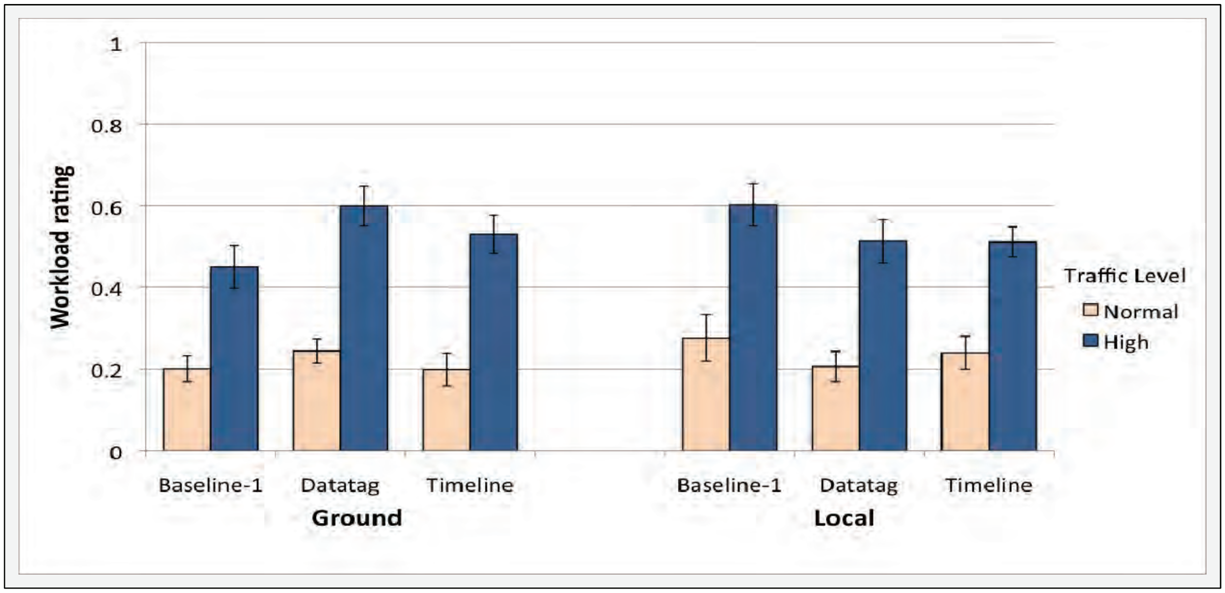

Figure 8: Workload. Effects of advisory (Baseline 1, Datatag, Timeline) and traffic level (normal, high) on controllers.

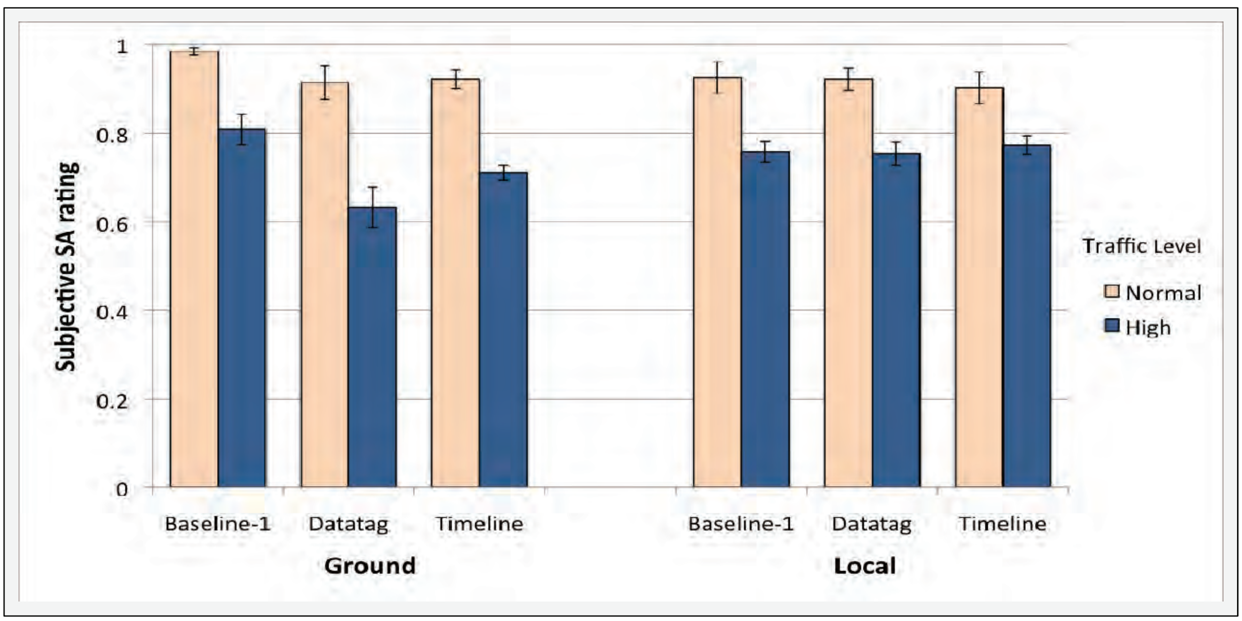

Figure 9: Subjective situation awareness. Effects of advisory (Baseline 1, Datatag, Timeline) and traffic level (normal, high) on controllers.

To better understand the difference in controller expectations and goals between the Baseline-1 and advisory conditions, a fourth advisory condition (Baseline-2, B2) was introduced where ground controllers were asked to meter traffic from the spot without SRP advisories. These results, shown in table 23, revealed that ground controllers perceived this task to be more demanding than the baseline condition (workload rating increased from 0.45 to 0.67, with 0.0 being low workload and 1.0 being high workload). This increase in perceived workload appeared to be offset when the SRP advisories were included.

TABLE 23: ANOVA RESULTS EVALUATING EFFECT OF ADVISORIES ON CONTROLLER WORKLOAD

Effect of Advisory on Workload (Performance Metric: Workload)			**Mean (Std. Err.)[1]**			
Position (Normal or High Traffic)	***Statistical Test***	***Statistical Significance***	***Base-line 1 (B1)***	***Data-tag (AD)***	***Time-line (AT)***	***Base-line 2 (B2)***
Ground (High Traffic)	F(3,21)=2.94	p=0.057	**0.45 (0.05)**	0.60 (0.05)	0.53 (0.05)	**0.67 (0.05)**
Local (High Traffic)	F(3,21)=3.06	p=0.050	**0.60 (0.05)**	0.51 (0.05)	0.51 (0.04)	**0.40 (0.05)**

[1] Means highlighted in bold text are statistically different at p<0.05. The workload scale ranges between 0.0 (low) and 1.0 (high).

Controllers echoed this finding during the post-study interview, indicating that if they were given the task of metering traffic from the ramp area, they would prefer to have an advisory tool like the SRP. Although this notion of metering departures from the spot is not currently integrated into ground control standard operating procedures, many major airports occasionally employ gate-hold procedures that share important features with the spot-metering concept. Application of the SRP algorithms to current-day gate-hold procedures is a potential avenue for further study.

Observations of the initial shakedown runs showed (under normal traffic condition) little change to the queue size, with or without the use of advisories. This indicated that the traffic level was not adequate for the controllers to accomplish manual spot metering. The high-traffic scenario provided enough demand, thus allowing them opportunities to exercise manual spot metering (Baseline-2 conditions). Hence B2 runs were made with only high-traffic scenarios.

Local Controller

Changes in perceived workload ratings between Baseline-1 and advisory conditions were not statistically significant for local controllers (fig. 8). Like the ground controller, the result showed no significant interaction between the use of advisories and traffic level.

The pair-wise comparison between B1 and B2 under high-traffic load in table 23, showed a statistically significant decrease in perceived workload (from 0.6 to 0.4). It is likely the ground controllers, who experienced higher perceived workload in this condition, were highly effective in metering traffic to the departure queue, and thus reduced the local controllers' task load. Like the ground position, there is no significant interaction between the use of advisories and traffic level.

Subjective Situation Awareness

The results show that the main effect on subjective situation awareness (SA) is traffic level (fig. 9). Local and ground controllers reported a decrease in subjective SA in the high-traffic condition.

Ground Controller

Planned pair-wise comparisons indicate that ground controllers showed a consistent pattern of decreased situation awareness when using the SRP advisories, compared to Baseline-1. This finding is consistent with controllers' comments in post-study interviews. Controllers stated that it was challenging to integrate checking the advisory with their natural flow/scan of the map, making it difficult to get into a rhythm. Controllers also reported that the advisory updating function, which could potentially change the spot release sequence and timing, was very disruptive to their own mental planning process, which is critical to developing and maintaining situation awareness. The interaction between the use of advisories and traffic level on subjective SA was not statistically significant.

Local Controller

SA was not impacted by the RS advisories for the local controllers. This finding is also consistent with controllers' post-study feedback where they indicated that the schedules provided by the RS were frequently consistent with their own plan. It is, perhaps, not surprising that controllers would find the SRP advisories to be less consistent with their own plans than the RS advisories. First, the goal of the SRP advisories is not consistent with ground controllers' present method of operation, whereas there is much greater alignment between the goals of the RS and the local controller. Second, the number of possible solutions that the SRP could generate was much greater than the number of possible solutions generated by the RS, which considered a more constrained problem space. The likelihood that the SRP will propose a plan inconsistent with the ground controller's plan is greater; therefore, updates to the SRP advisories are more likely to result in changes that disrupt the controller's planning. The interaction between advisory and traffic level on subjective SA is not statistically significant for the local controller.

Objective Situation Awareness

Ground Controller

The objective SA results for the ground position, shown in figure 10, showed no statistically significant effects of traffic level or advisory type. The interaction between advisory and traffic level for objective SA is statistically significant, however. The objective situation awareness decreased at the high-traffic level, but not in the normal traffic.

Local Controller

The local controllers' results showed no main effects or interactions for objective situation awareness.

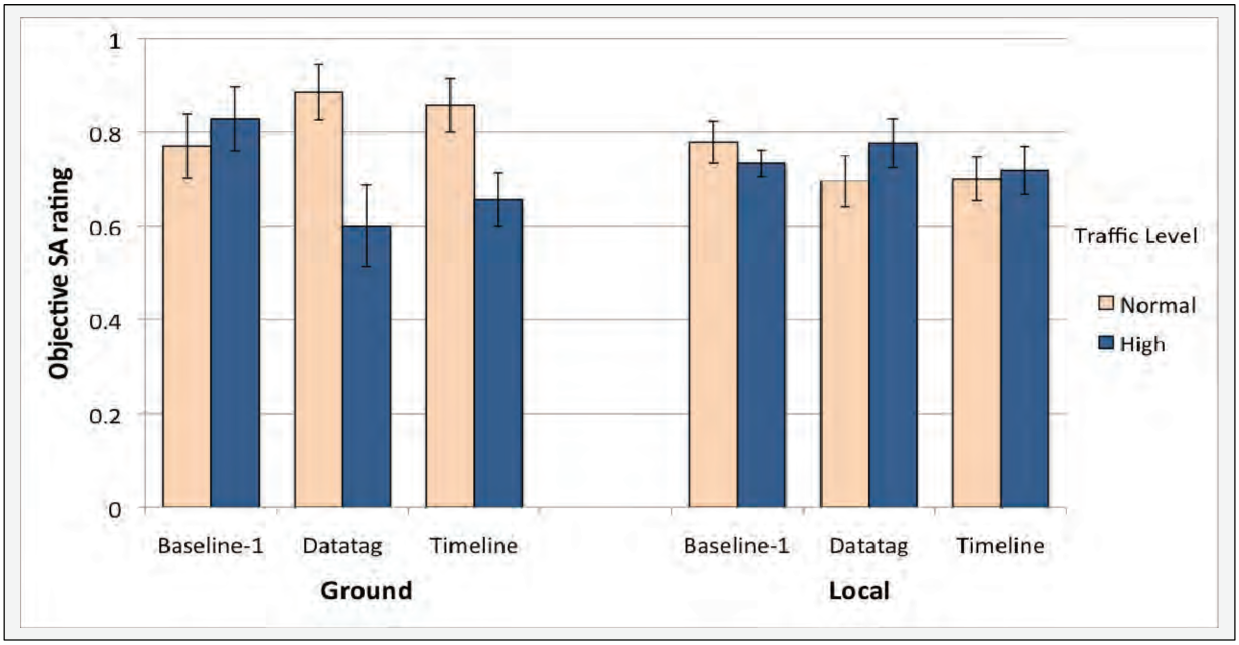

Figure 10: Objective situation awareness. Effects of advisory (Baseline-1, Datatag, Timeline) and traffic level (normal, high) on controllers.

Usability

No differences emerged in controller metrics between the datatag and timeline advisories; however, there was a consistent numerical trend for higher workload and lower SA when ground controllers used the datatag advisory. This trend is consistent with controllers' post-study feedback, where they expressed a preference for the timeline over the datatag format on the ground control position. Controllers indicated that the timeline advisory made it easier to plan ahead and kept clutter off the map, and they felt like they recognized updates and sequence changes more quickly. Controllers also reported difficulty locating the next-in-sequence aircraft on the map when using the datatag format.

The controllers noticed some artifact in the simulator that may affect workload and SA. Factors included: limited route selection (use of Full (EF), Inner (EG), and Outer (EH) taxi routes), little use of bridge traffic (east-west airport terminal crossings), and uniform taxiing speed. These artifacts made the traffic movement appear less realistic. Some of these artifacts, like applying nonuniform taxiing speed, will be addressed in the next series of simulations.

HUMAN-IN-THE-LOOP LESSONS LEARNED AND LIMITATIONS

This section presents the human factors lessons learned and shows some of the limitations of the simulation environment for both controllers and pseudo-pilots.

Human Factors Lessons Learned

The following are lessons learned about controller-system interactions based on the comments from post-study interviews with the controller participants:

- At the ground position, controllers reported preferring to use the timeline advisories over the datatag advisories. They indicated that it was difficult to locate which aircraft was next in sequence using the datatag advisory, particularly during a heavy traffic scenario, because this required a detailed search of the map display. The timeline display, because it included the spot information for each aircraft, made it easy to locate the next aircraft in the spot release sequence. Controllers commented that the datatag advisory contributed to clutter on the scopes, which was eliminated with the timeline advisory. At the local position, there was no reported preference between the timeline and datatag advisories.
- Updates to the sequence order in the SRP that affect the top three or four aircraft were reported as very disruptive to planning.
- Sequences recommended by the SRP were found to be frequently inconsistent with the controllers' natural flow or scan, making it difficult to establish a "rhythm" while using the advisories.
- The controllers in this experiment commented that the advisories took away a lot of their planning. While this impression likely contributed to the reduction in reported workload, the fact that planning was one of the tasks allocated to the automation also likely contributed to the observed reduction in situational awareness. A challenge for future development will be to provide support to the controllers such that self-reported workload is reduced (or remains constant under increasingly complex conditions) while maintaining or enhancing situational awareness. Concepts related to integrating with, rather than replacing, controllers' planning activities should be explored.
- The timeline display provided a "look-ahead" feature, which controllers reported viewing positively, as it gave a sense of how much traffic to expect in the near future.
- Comments indicated that controllers found it was difficult to adjust to using spot release times that were not based on how long an aircraft has been waiting at the spot. They indicated that in their experience, the pilots of waiting aircraft would be calling the controllers and complaining if forced to wait so long in the real world, or if they saw another aircraft released ahead of them that had been waiting less time. This suggests that an important key to successful implementation of the SARDA tools would be educating the airlines, as well as the controllers, about how the tools prioritize spot release to mitigate possible complaints and/or nonconformance by pilots.

- Metering from the spot concept must also ensure that the ramp area does not get congested, which can negatively affect both outbound and inbound traffic flow.
- Controllers indicated that if they were given the task of metering traffic, they would prefer to have the timeline SRP advisor rather than to meter the traffic without an advisor. Although the metering goal in the baseline condition results indicated that controllers were able to successfully operate without an advisor, controllers appreciated that the advisor alleviated some of the workload and pressure associated with that goal.
- Several potential changes to the simulation environment were suggested that could enhance the fidelity (and, thus, the generalizability) of the simulation, including:
  - Add realistic simulation of ramp congestion.
  - Include occasional gate changes for arrival aircraft.
  - Pseudo-pilots should occasionally make requests (e.g., for the full-length route if the aircraft is a heavy so they can have longer runway)
  - Vary the taxi speeds of aircraft
  - Allow use of Mike taxiway (to offload departure congestions on the Lima taxiway), and Papa taxiways (allowing the use of the perimeter taxiway for runway 17L arrivals, but also to allow simultaneous crossings of runway 17C, for aircraft destined at different terminals).

Simulator Limitations

The simulation environment in the study differed from "real world" operations at DFW in several ways.

No "out-the-window" view. Controller participants used computer-generated (plan-view) map displays to observe traffic for depictions of the ground and local controller displays used in the simulation. SARDA tools were integrated with these displays. A potential concern for field implementation of any visual-display-based automation is attention/gaze management (i.e., appropriate "heads-up" versus "heads-down" time). Because the SARDA simulation did not employ a "heads-up" out-the-window view, this potential concern was not addressed in the current study.

Flight strips were not used. Information normally obtained from flight data strips (e.g., initial departure fix) was displayed as part of the data block associated with each aircraft. However, controller participants reported that, in real-world operations, they also used flight data strips to identify departure sequence as well as serving as memory aids for the status of a given aircraft (e.g., whether an aircraft has been cleared for takeoff). Additionally, given the dynamic updating feature of the SARDA advisories, it is unclear how the advisories might be integrated in a paper flight strip environment. Because flight strips were not included in the current simulation, issues associated with integration of the SARDA advisories into a paper or electronic flight strip environment were not explored.

Taxiway and runway limitations. The algorithms used in the SARDA tools were programmed with various constraints on how taxiways and runways would be used. These constraints facilitated the predictive capabilities of the algorithms necessary for future planning. Participants were informed of these constraints, and were asked not to use the runways and taxiways outside of those constraints (e.g., participants were instructed not to depart aircraft on Runway 17C). Field implementation of these algorithms will require a greater level of flexibility to account for off-nominal or unplanned events.

Keyboard/mouse data-entry procedures for departures. In order for the SARDA algorithms to predict future aircraft positions, controllers were required to inform the system of critical taxi commands (e.g., assigned departure taxi routes). Because these commands were issued via voice commands to the pseudo-pilots, controllers were also required to make keyboard/mouse data entries to inform the system about the commands just issued to the aircraft, which created an additional procedural step for controllers. Errors in data entry created inaccuracies in system predictions that were manually corrected in real time during the simulation by members of the research team. Error types and frequencies were not analyzed.

Pseudo-pilots had a restricted range of actions they could take. Controllers were informed during training about limitations imposed on the pseudo-pilots during the simulation. For example, the pseudo-pilot interface did not permit go-arounds, therefore one strategy for mitigating potential operational errors was not available to controllers. Operational errors (e.g., loss of separation events) were not analyzed.

Highly static/predictable traffic flow. Controller participants commented during the post-experiment debrief that the traffic flow was much more predictable in the simulation than in the real world. For example, all aircraft in the simulation taxied at the same speed and did not deviate from assigned routes. The weather conditions remained unchanged and were not introduced as factors in the simulation. It is unclear the extent to which controllers' behavior may have been influenced by the increased predictability of traffic flow.

FUTURE RESEARCH

The findings documented in this report describe a surface automation proof-of-concept that completed the first round of human-in-the-loop (HITL) testing, providing NASA researchers with an initial view into this complex domain. The HITL results pose more research questions, and thus offer opportunities for future research and implementation techniques to improve the current model as well as inspiring the next iteration of the tool. Five key areas that should be addressed are:

<u>Incorporation of the arrival traffic into the Spot Release Planner (SRP) concept</u>. The current implementation of the SRP does not explicitly include arrival aircraft in its algorithm. Incorporating arrival aircraft in the strategic planning phase will allow for providing tighter time windows for spot release times, and can lead to less uncertainty in the resulting system. Moreover the controller would be required to simply release the aircraft at the resulting spot times, instead of planning for the slot among a stream of arrivals from which to release the aircraft.

<u>Ramp area congestion reduction</u>. Implementation and testing of the SRP Long Term (SRP-LT) concept will address congestion issues in the ramp area by providing the airlines with expected time of release from the spot, thus allowing the aircraft to remain at the gate. A "gate management" algorithm may be required to assign gates to aircraft and efficiently manage the gate holding policy.

<u>Improvements to robustness due to uncertainties in the system</u>. This research area will focus on ways to introduce factors such as delay in controller/pilot response time, variation in aircraft taxi speed, and errors in aircraft trajectory prediction or surveillance systems, to systemically add uncertainty into the system and thus demand robustness in the scheduling algorithms. Advanced algorithms for aircraft trajectory prediction will reduce uncertainties, whereas alternate rolling planning horizon schemes could provide more robust and stable solutions.

<u>Enhancements to user interference</u>. Inputs collected from the controllers can help further the development of the user interface, to transform the system into a decision support tool (DST), by providing "control knobs." These control knobs can allow the user to change various system parameters such that the system will work in concert with the Air Traffic Management (ATM) plan set forth by the air traffic managers. This will also involve modifying the algorithms to incorporate these additional constraints.

In addition, improvements to the user interface to enhance usability of the tool should be pursued. Alternative user interfaces (i.e., to the electronic flight strip) should be investigated to improve user interaction and potentially improve situational awareness, such as using a touch-screen interface.

<u>Scheduler enhancements</u>. Enhancements will include exploring the practical methods of using the unified approach (taxi scheduler) mentioned in the *SARDA Concept of Operations*. The taxi scheduler could solve a traffic-scheduling problem that would cover the entire airport surface. The merit of such a scheduler is the ability to include both arrivals and departures in the optimization model, simultaneously optimize all departure and arrival runways, and the ability to design optimal 4-D trajectories for all aircraft.

The current DFW study shows the potential of the surface management tool to aid ground and local controllers with managing aircraft in the active movement area. The five future enhancements stated above are necessary to fortify the tool and transform it into a decision support tool. But in order to reach that point, a series of subsequent tests are needed to investigate incremental improvements along the way. If the goal is to provide full airport management and efficiency, it will require the collaboration of the ramp controller and the corresponding ramp management tool, which is also another area needing research.

AUTHORS' BIOGRAPHIES

Ty Hoang received his B.S. and M.S. degrees in Aeronautical Engineering at the California Polytechnic State University at San Luis Obispo, California, in 1991 and 1994, respectively. He started his career working on a pseudo-aircraft piloting system at NASA Ames Research Center. Later, he participated in the field testing of the Traffic Management Advisor (TMA) system at DFW in the mid-1990s. In 2003, he led the development of the complex Multi-Center TMA (McTMA) simulator. The robustness of the McTMA simulator contributed to the successful field tests in 2004; he now leads the development of the airport surface simulator. Mr. Hoang is a Senior Member of the American Institute of Aeronautics and Astronautics.

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Dr. Leonard Tobias received his Ph.D. from the Polytechnic Institute of Brooklyn in 1969. He has been engaged in ATM research at NASA Ames Research Center for over 40 years.

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APPENDIX A: THE HIGH-FIDELITY SURFACE SIMULATOR FACILITY

Physical Layout

All three SARDA real-time human-in-the-loop (HITL) experiments (initial shakedown, shakedown, and data collection runs) were conducted at the FutureFlight Central[1] (FFC) facility at NASA Ames Research Center. The FFC is a two-story building, with four rooms on the first floor while the second story houses a high-fidelity 360-degree simulated out-the-window visualization of an air traffic control tower. The SARDA HITL experiment reported in this paper did not use the unique visualization capabilities of the FFC. The researchers intend to capitalize on the tower's full-surround visual in future experiments, after further tool maturation.

The first floor provided the staging area to conduct the simulations. The Test Engineer Room, Controller/Pilot Room, and Briefing Room (fig. A1) are located on the first floor.

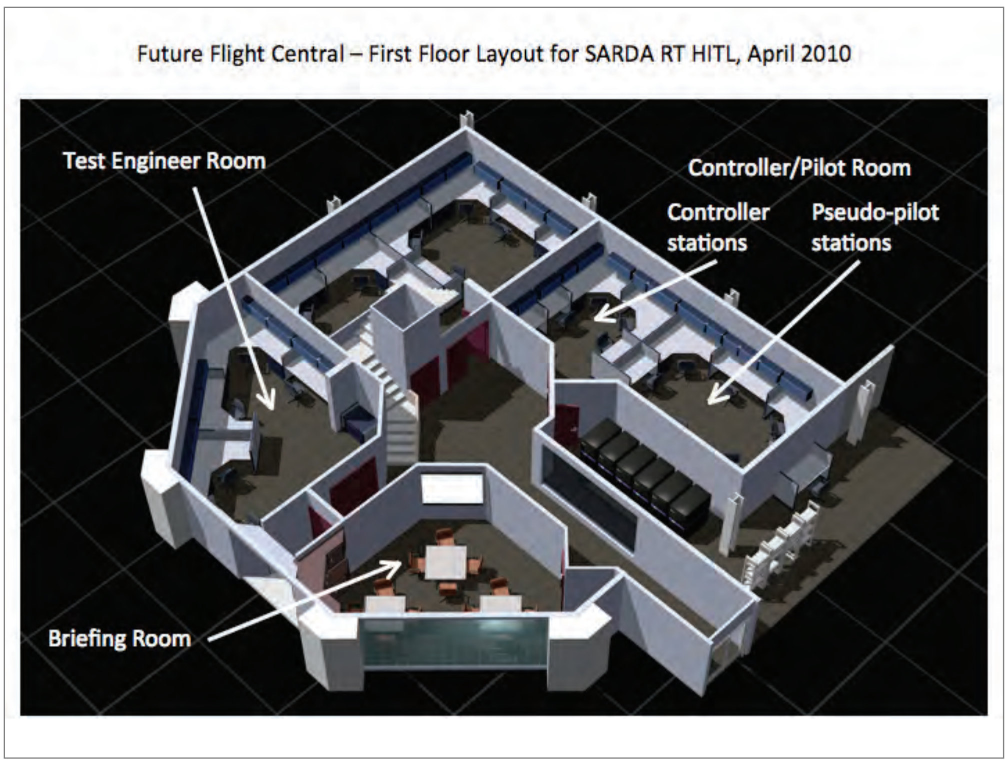

Figure A1: FutureFlight Central's first-floor layout supporting the SARDA real-time human-in-the-loop simulations (April 2010).

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[1] NASA Ames Aviation Systems Division, FutureFlight Central main page, http://www.aviationsystemsdivision.arc.nasa.gov/facilities/ffc/index.shtml, Jan. 2013

The Test Engineer Room

The Test Engineer Room housed the core SARDA simulation software. From here, the researchers monitored the health status of the system, recorded simulation data, and broadcasted public announcements to the simulation participants. The core software is comprised of two major software systems, the Airspace Traffic Generator (ATG)[2] and the Surface Management System (SMS)[3]. Within the ATG, the subsystems were comprised of the Ground Manager (GM), Super Ground Pilot Station (Super GPS), and the Air Traffic Message Translation Engine (ATMTE). The GM controls the ATG simulation environment while the Super Ground Pilot Station (GPS) acts as an automated pilot under the guidance of event-driven scripted commands. The ATMTE's task is to translate communication messages between ATG and the SMS Cap Server interface (fig. A2).

Subsystems used by SMS include the Communications Manager (CM), CM User Interface (CMUI), Model, Client Graphical User Interface (GUI), and the CapServer(fig. A3). The CM acts as the central communications hub of the system, collecting data from external sources, and distributing data to other SMS components. The CMUI provides the user interface for the CM and allows the user to display or modify component connection status. The Model provides aircraft modeling capability within SMS. The CapServer (Collaborative Arrival Planner)[4] provides a communication interface with external programs such as ATG.

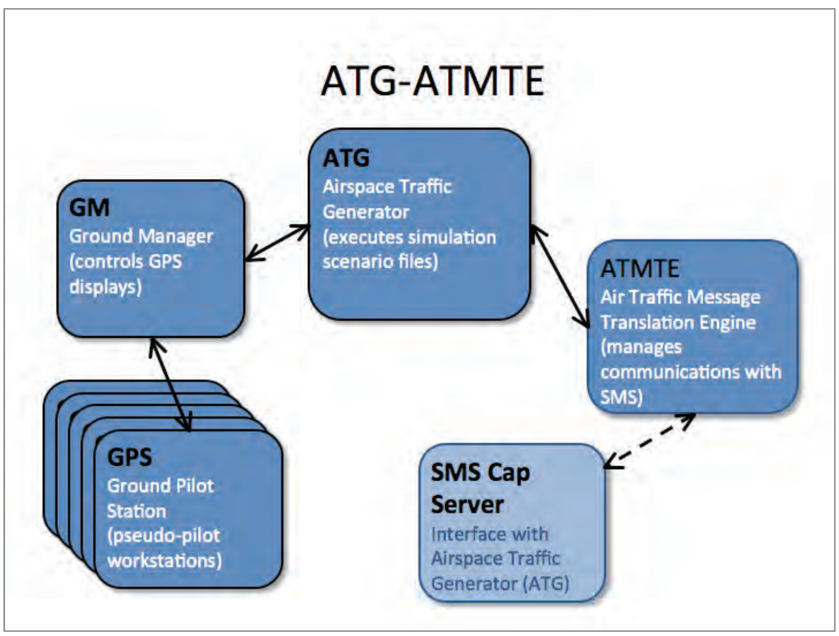

Figure A2: ATG-ATMTE and SMS Cap Server functional diagram.

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[2] SAIC: Airspace Traffic Generator: User's Manual Supplement, Rev. 2.6, 2011.

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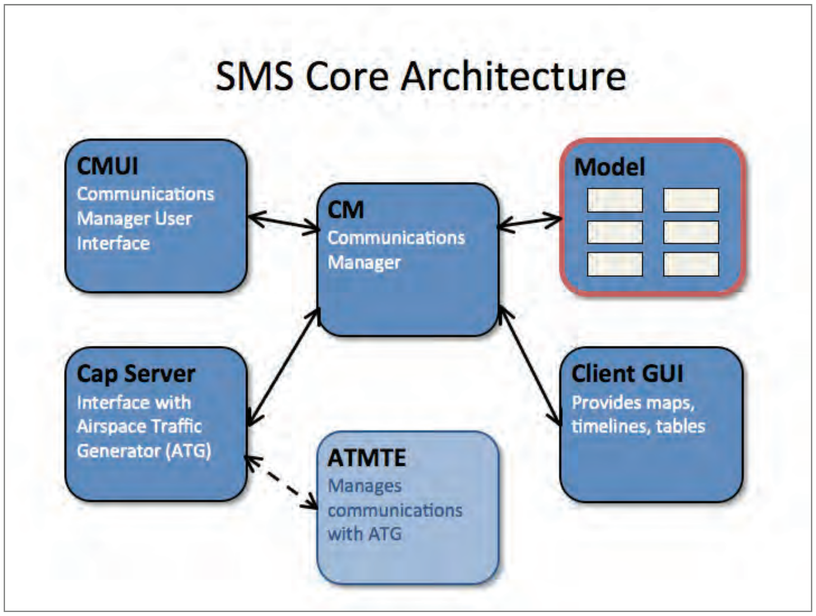

Figure A3: SMS Core Architecture.

The simulation engineer occupied the Test Engineer room. The simulation engineer's responsibilities included bringing up all simulation components at start time and monitoring them during the run to ensure system integrity. This person also initiated and terminated all data recordings from both the ATG and SMS systems. Other logistics tasks included archiving simulation log files from the ATG and SMS systems after each run for later analysis, defining the layout of the Controller/Pilot Room, and setting each workstation's configuration.

The simulation engineer made announcements over the public address system to inform controllers, pilots, and researchers about simulation run start and end times. The simulation engineer also used software to automatically record the controller's and pilot's radio communications, and organized, collated, and archived the data for each run for post-run analysis. Preparatory duties included the configuration of the communication units situated at each controller, pseudo-pilot, and researcher stations. Figure A4 illustrates the layout of the Test Engineer Room and the Controller/Pilot Room. Included in the figure are the ATG and SMS systems and how they are connected to the respective users, be they controllers or pseudo-pilots (PP). The orange solid line represents the ATG system, while the blue dashed line shows the SMS connection.

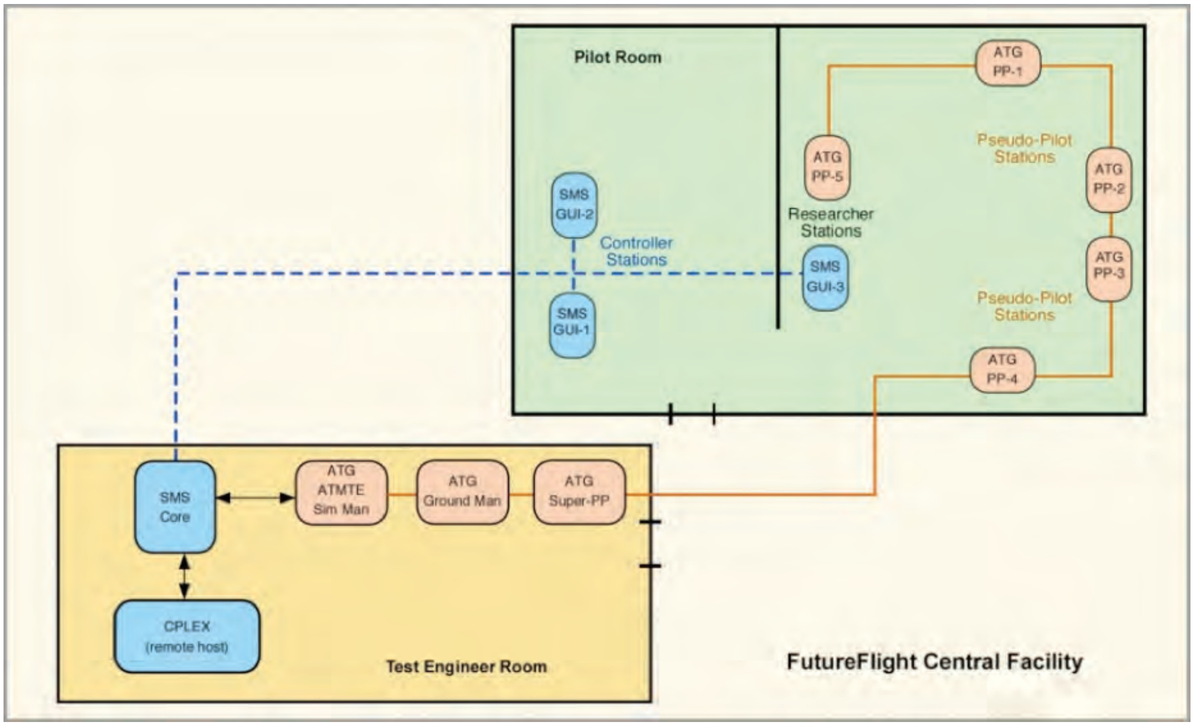

Figure A4: SMS and ATG system and users situated at the FutureFlight Central.

The Controller/Pilot Room

As shown in figure A1, the Controller/Pilot Room is broken down into two smaller rooms with the left side housing the controllers and the right side containing the researchers and pseudo-pilots (PPs). The configuration used in the SARDA runs is shown in figures A5 and A6. These two graphics show in detail the controller and pseudo-pilot positions, and their area of coverage over the east side of the Dallas/Fort Worth (DFW) airport. The controllers took residence on the left side of the room while pilots took the right side of the room. Between them were the room divider and the researcher stations.

The left side of the room contained three SMS stations. The ground and local controller each had an SMS workstation configured for their domain of control. The third station was a spare used during visitor demonstrations. The stations ran the SMS GUI clients, which connected to the SMS core processes running in the Test Engineer Room. Seated next to the ground and local controllers during each simulation run were the human factors observers who noted controller comments on the simulation system, scheduling advisories, traffic management preferences, and suggestions for simulation improvement. An additional researcher (moving between controller and pilot partitions) monitored the Controller/Pilot Room to provide technical support, such as systems startup/shutdown for each run, and to quickly convey messages to researchers located in the pseudo-pilot partition of the room.

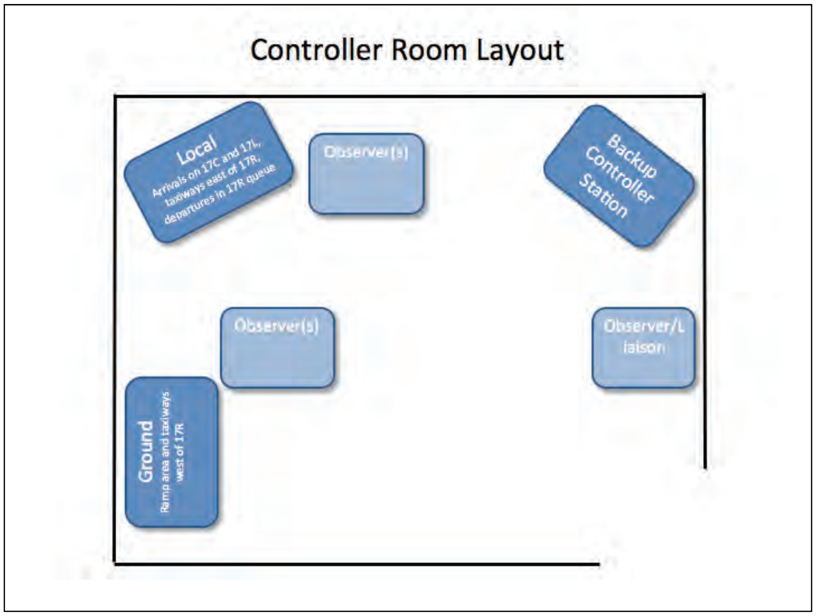

Figure A5: Controller/Pilot Room, controller partition (left side of room).

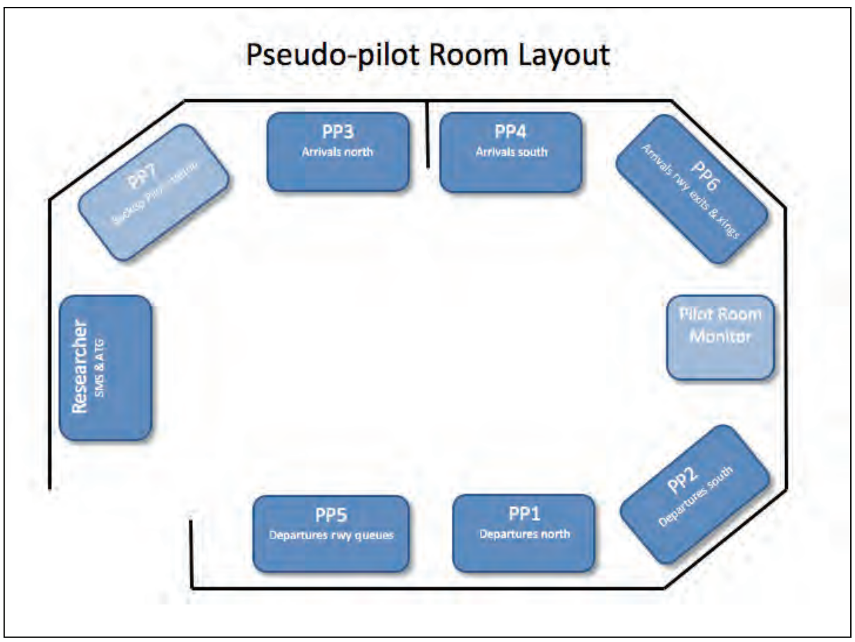

Figure A6: Controller/Pilot Room, pseudo-pilot partition (right side of room).

The right side of the Controller/Pilot Room contained seven GPS stations, which were staffed by a pseudo-pilot. The layout contained six active stations and one spare unit. Additionally, the Researcher SMS and GPS stations were also located on the same side of the partition. The Researcher Station allowed the researchers to monitor both SMS and ATG systems side-by-side at one location and near the subjects. Depending on the role, each pseudo-pilot controlled either all departures or all arrivals within a designated geographical area on the airport surface (see Appendix D: Pseudo-Pilot Training Material).

Three pseudo-pilots controlled departing aircraft (denoted as PP1, PP2, and PP5), and three controlled arriving aircraft (denoted as PP3, PP4, and PP6). Departures typically started their taxi from the ramp area, moving into the spots and to their departure runways. A spot represents a location where a hand-off of control is made from the tower to the ramp controllers. Arrivals were typically created a few miles upstream of the runway threshold, where they would land, cross the active runway (17R), and taxi to the arrival spots.

Supplementing the pseudo-pilots were automated (computer-controlled) pilots. The automated pilots were typically used to control traffic at ancillary portions of the airport surface or for tasks that were not of main interest to the study. For example, aircraft entering the system 10 miles away from the airport, aircraft assigned to any taxiway heading toward the west side of the airport, or arrivals landing on the far east runway 17L that needed to be guided to runway 17R before transferring ownership to the PP6 position

A researcher assigned to the room monitored the pseudo-pilots to answer any questions and resolve the occasional pseudo-pilot computer-entry error. Another researcher sat at the Researcher station to monitor the Ground and Local SMS Controller stations and the GPS station. This researcher also watched for system or performance anomalies. Additionally, the Researcher's SMS displays were configured to make screen recordings of the monitor. The video was recorded into Moving Picture Experts Group (MPEG) movies for making demonstrations and post-run data analysis. During a run, the video contents were routed to the video projector located in the Briefing Room.

The Briefing Room.
The Briefing Room hosted visitors, observers, and additional researchers, and was a place where people could congregate to observe the live broadcast of the simulation without disrupting the participants during the data runs. Live audio between the controllers and pseudo-pilots was also fed into the Briefing Room, with the controller feed (ground or local) selectable. This room allowed for open discussions and questions between visitors and researchers. It also served as the pre- and post-run briefing area.

Recording Capabilities

Each data collection run during the HITL included video recordings of the simulation displays and audio recordings of the voice communications between controllers and pseudo-pilots. The video recordings consisted of the screen capture of the Researcher SMS display during a run, captured into an MPEG movie. Each recording used the *xvidcap*[5] software running on the Researcher Station. The researcher observing the HITL from the Researcher Station in the Controller/Pilot Room was responsible for starting and stopping the recordings at the appropriate times.

[5] Tool used to capture video on an X-Windows display, as individual frames or MPEG video. http://xvidcap.sourceforge.net, July 31, 2012.

Audio/voice communication recordings of the interchange between controllers and pilots were made at each station during each simulation run. One track recorded communications on the Ground radio frequency, and another on the Local frequency. Each audio recording was done using the SimPhonics Software and Hardware Solution running on a Windows XP machine. The simulation engineer in the Test Engineer Room was responsible for starting and stopping the recordings.

Hardware Configuration and Usage

Hardware Configuration

This section describes the various hardware systems used for the SARDA HITL run in April 2010. ATG ran on a Sun Ultra45 with Solaris 10. The Ultra45 was a Dual Sparc 1.6 GHz with 4 GB of memory. ATMTE, SMS core processes, and SMS GUI displays ran on CentOS 5.4 x86_64 Linux systems. Two Apple Mac Pro workstations with two quad-core Intel Xeon 3.2 GHz processors and 10 GB of memory were deployed to run computationally intensive processes. Three HP xw8200 workstations with dual Intel Xeon 3.6 GHz processors and 6 GB of memory running Windows XP Professional 2002, Service Pack 3 were used to run the other subsystems of the simulator such as the GM, Super GPS, and the Pilot GPS.

Input Device

All workstations (Solaris, Linux, and Windows) used a keyboard and mouse for user input. Additionally, voice communications between controllers and pilots were transmitted using SimPhonics digital radio headsets.

Display

The workstation displays used for the SARDA HITL are described in this section. In the Test Engineer Room, the ATG workstation had one 24-inch display. The GM and Super GPS workstations each had one 20-inch display. The SMS core processes workstation had one 24-inch and one 19-inch display. In the Controller/Pilot Room, the controller workstations used multiple 24-inch displays: ground had three, local had two, and the spare station had two. The Researcher workstation had three 20-inch displays. Each pilot GPS station had one 20-inch display. The SimPhonics[6] radio systems had one 15-inch display each. The following figures show the test engineer room (fig. A7), ground and local displays (figs. A8 and A9), pseudo-pilot station (fig. A10), and the researcher station displays (fig. A11).

Network

The SARDA HITL used the 100 Mbit/s full duplex network infrastructure supplied by the FFC facility. No other network upgrades were required to support the SARDA experiment.

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[6] Provider of simulator's audio and voice recording system. http://www.simphonics.com, July 31, 2012.

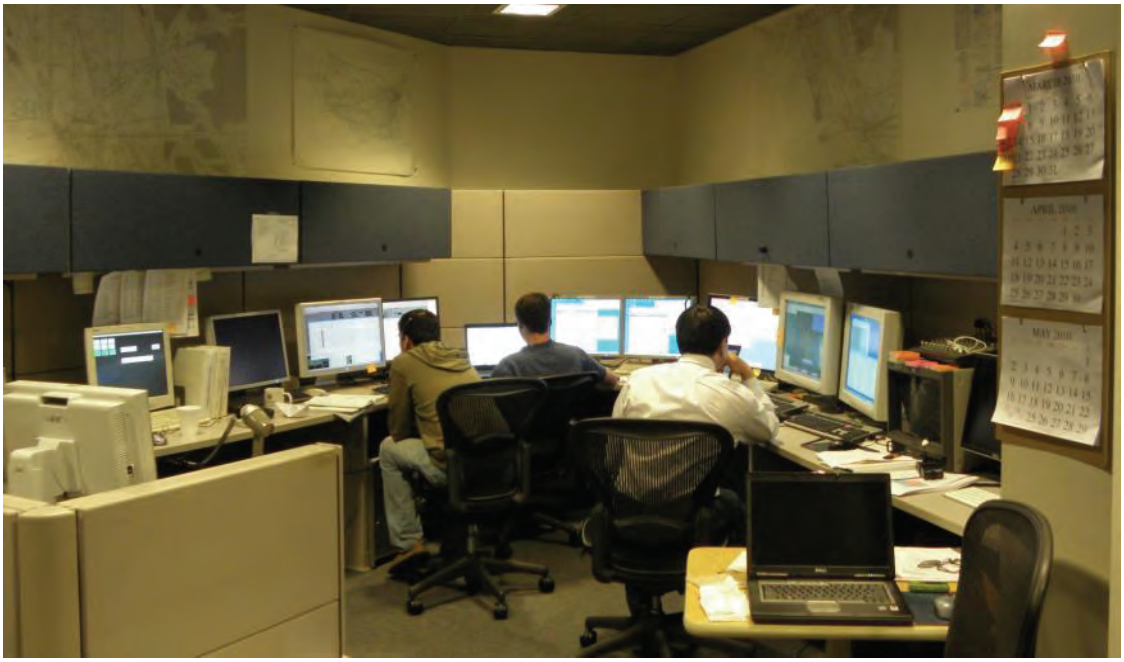

Figure A7: Test Engineer Room.

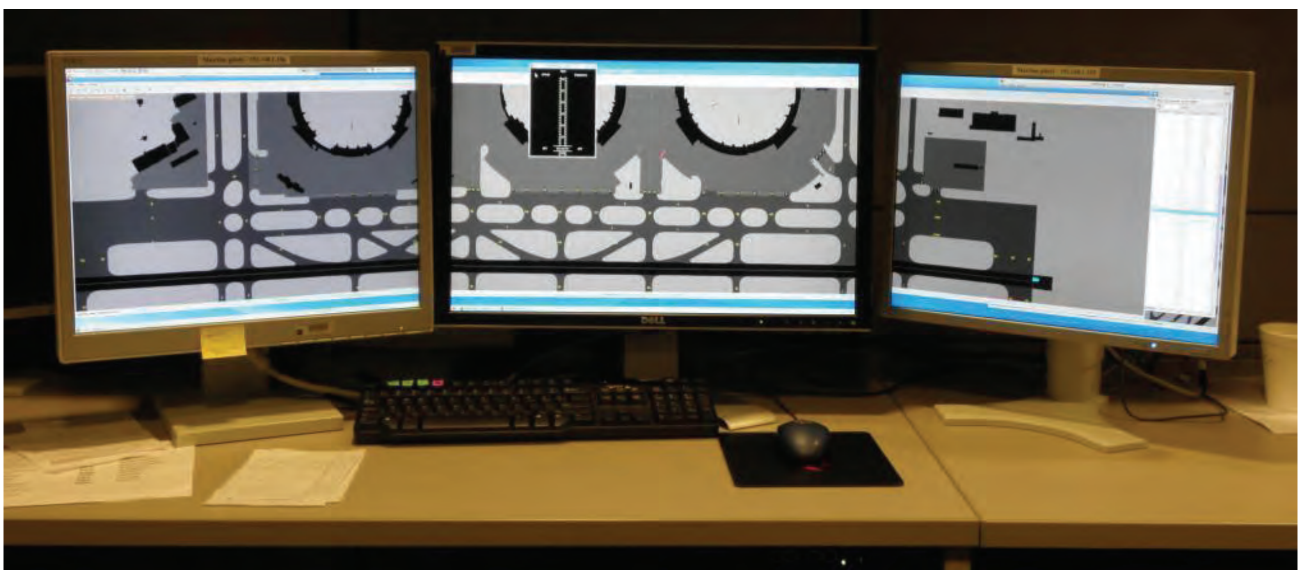

Figure A8: Ground Controller Display.

Figure A9: Local Controller Display.

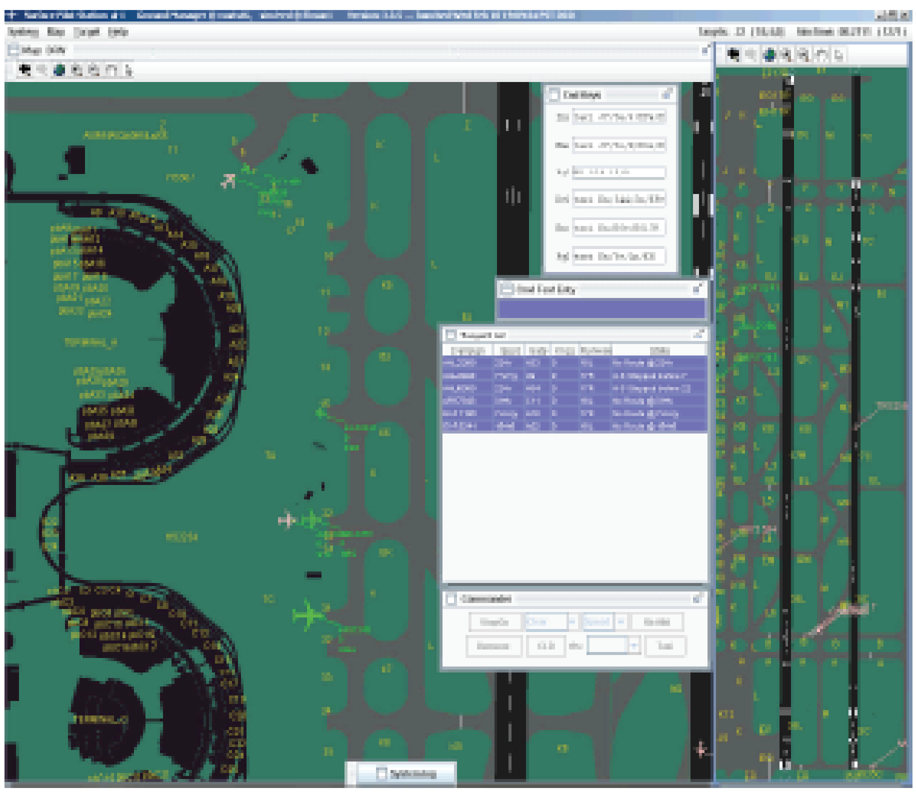

Figure A10: Pseudo-Pilot Displays.

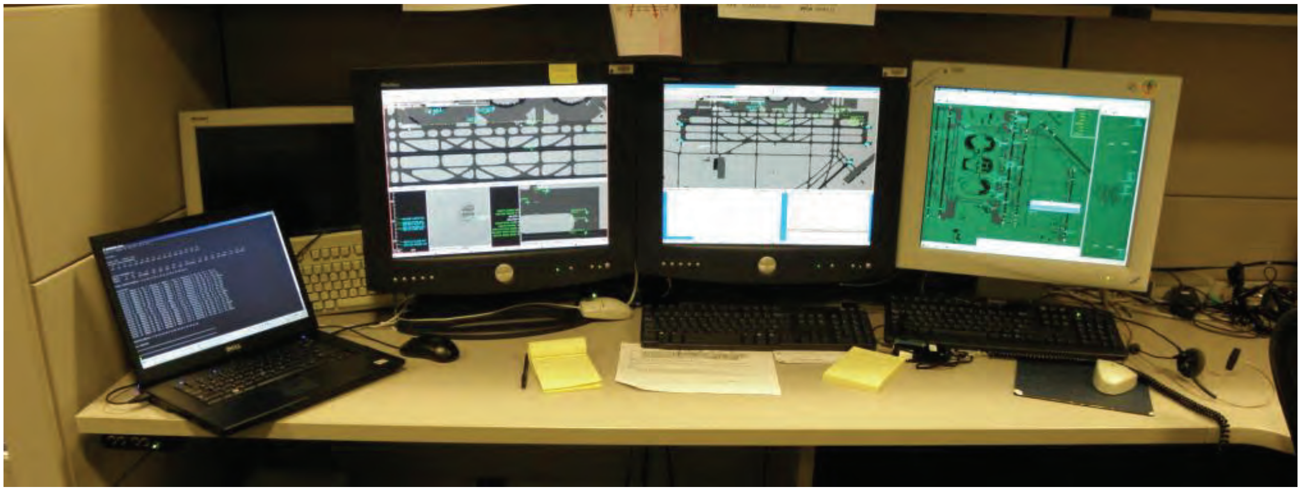

Figure A11: Researcher Station and displays in Controller/Pilot Room.

Software Configuration and Usage

The SMS software operates in real time and includes a mature user interface thus making it well suited for use in HITL studies. Modular (plug-in) components can be implemented within the SMS model to interact with surface schedulers. SMS has knowledge about the airport layout and aircraft dynamics. It can create shortest path taxi routes from a flight's current position to its destination (departure runway or arrival spot). SMS requires aircraft track inputs, and ATG provides the simulated traffic.

Airspace Traffic Generator (ATG), [Version 2.16.2]

ATG provides simulated aircraft track data to the SMS system. ATG, as used during the SARDA simulations, is made up of three major components: the Ground Manager, Ground Pilot Station, and the ATMTE messaging translator. The components run under various hardware and operating systems, but they work cohesively to provide two major functions. Besides being a target generator, ATG also provides an interface to each pseudo-pilot, allowing for the control of multiple aircraft, typically up to eight. During the SARDA runs, the Ground Manager was configured to run in the Test Engineer room while the Ground Pilot Station ran in the Controller/Pilot Room.

The Ground Manager (GM), [Version 3.3.5]. The GM provided communication of flight plans and aircraft track data between SMS and the Ground Pilot Stations. The GM also managed the connectivity between multiple pilot stations.

The Ground Pilot Station (GPS), [Version 3.3.5]. The GPS is the primary user interface to the pseudo-pilot. Within the GPS, the pilot can issue various aircraft commands such as speed and heading, as well as routing information for the aircraft to follow. Each pseudo-pilot typically controls multiple aircraft and assigns aircraft movement based on verbal communication with either ground or local controllers. As the aircraft exits the control domain of one pseudo-pilot, it is handed off to the receiving pseudo-pilot (fig. A12).

SARDA Ground Pilot Station Display

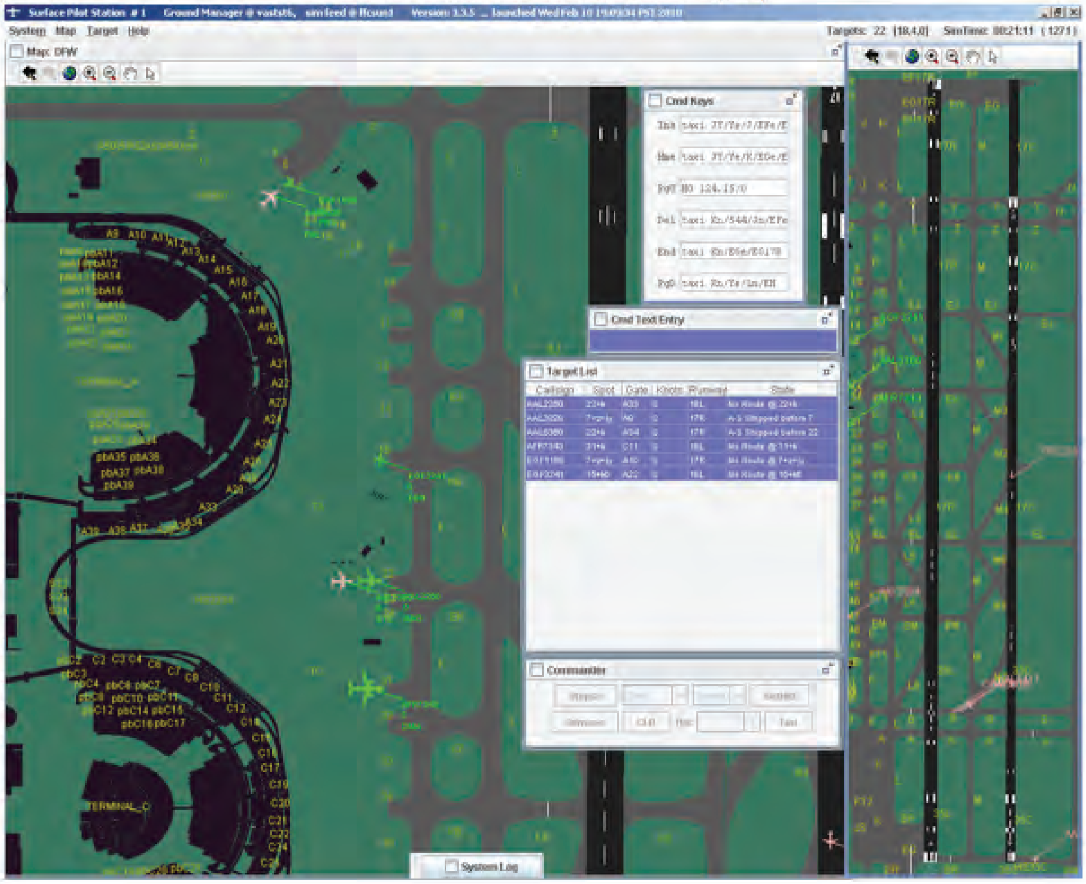

Figure A12: The Ground Pilot Station display.

Two configurations for GPS were used in the SARDA HITL: Super GPS and pilot GPS. The Super GPS executed prescribed command files, which contain automated instructions to control aircraft that were not within the scope of interest of the present study. It was configured to show the entire airport surface so that a researcher could monitor and resolve traffic artifacts. Super GPS ran on its own Windows NT workstation in the Test Engineer Room. GPS displays for the pseudo-pilots ran on separate Windows workstations in the Controller/Pilot Room, one for each pseudo-pilot. They were configured to show the specific area of the airport surface assigned to each pilot. Pilots received verbal instructions from controllers, located the flight on the GPS, and issued the corresponding aircraft commands.

Figure A12 shows a sample GPS display that includes various display elements. The map of DFW is shown in green, depicting Terminals A and C (dark semicircles) located on the left-hand side of the picture. Shown on the terminals are the gate numbers (e.g., A33, C17) and two aircraft (in pink) heading toward spots 7 and 22. On the right-hand side of the figure is an overlaying map of the arrival (17C) and departure (17R) runways, with aircraft flowing from the top to the bottom of the map. Also shown is the command keys window, "Cmd Keys," which assigns regularly-used instructions to the aircraft. Other instructions can be typed into the "Cmd Text Entry" window to manipulate aircraft movement. Below that is the “Target List,” which displays all aircraft owned by this particular pseudo-pilot. Near the bottom of the window column is the “Commander” window that allows aircraft controls to be made via the mouse instead of using the keyboard.

The SARDA HITL required a few changes to ATG ground and GPS maps for alignment with the SMS airport adaptation. Spot locations were moved a few feet back into the ramp areas for Terminals A, C, and E, so that aircraft stopping at a spot would not have its nose encroaching into the taxiway on the SMS display. Some node locations were modified to more closely match up to the SMS airport adaptation. The ATG aircraft-type database was changed to use lower taxi speeds in turns and ramp areas for selected aircraft types. The anti-stack (in-trail anti-collision functionality in ATG) distance between targets was set to 1.6 times the fuselage length of the trailing aircraft to mimic nominal separation distance based on SME feedback.

Air Traffic Message Translation Engine (ATMTE), [Version 1.4]. ATMTE manages the communication of flight plans and tracks data from ATG to SMS. ATMTE acts as a translation engine, converting information such as node names (system adaptation specific information), and messaging type and format, between the ATG and SMS. Data transfer is achieved via Transmission Control Protocol/Internet Protocol (TCP/IP) sockets between ATG and the CapServer component of SMS. For the SARDA runs, ATMTE shared a Linux workstation with the SMS core processes in the Test Engineer Room.

Aircraft List or Scenario File. The “aircraft list” defines the traffic scenario to be run in the simulation. Aircraft details such as call sign, aircraft type, departure and arrival airports, and spots, are specified in this text file. ATG reads in this file during initialization to generate the aircraft traffic. As ATG generates track for these aircraft, they are sent over to SMS along with other types of information such as flight plans. The scenario file defines the number of departures and arrivals in a simulation and when each aircraft is to be activated (e.g., produce first target return on a radar system). SARDA runs had departures simulated at the gate moving toward takeoff and up to 10 nautical miles (nm) after being airborne. Arrivals would approach from the final approach fix (about a 10 nm radius from the center of the airport, not at end of runway threshold), land, and then taxi to the spot and gate. More details on the scenario generation process are included in *Appendix E: Scenario Development.*

Command List. Command files define aircraft ownership based on assigned sectors, for both automated pilots and the human pseudo-pilots. It specifies flight characteristics (such as assigned speed) and handoff characteristics. The Command List can control aircraft in the ramp areas, west-side traffic, and takeoffs on runways 17R and 18L for departures. For arrivals, the automated sectors can control landing on runways 17C, 17L, 18R, and 13R to runway crossings, and the taxi routes to spots and gates. For this study, turboprops using runway 13L were not simulated. Two simulation traffic levels were defined: normal (40 departures, 40 arrivals) and heavy (64 departures, 60 arrivals) (see Appendix F: Historical Input Files for Scenario Generation). The command list may include instructions for the automated pilot to hand off aircraft to a pseudo-pilot controlled sector. Conversely, pseudo-pilots can also hand off aircraft to automated sectors; for example, actions such as moving the aircraft from the spot to the gate and removing it from the simulation after some predefined period.

Surface Management System (SMS), [Version 8.3]

SMS is organized into multiple components such as the CM, CMUI, Model, GUI, and CapServer.[7] Of these, integration of the SARDA scheduling algorithm into SMS software is done via one of the plug-in components in the SMS Model Plug-ins module (fig. A13). The model's plug-in architecture was developed using a notional concept depicted in figure A14. From the figure, the Spot Release Planner (SRP) is associated with the Scheduler module embedded within the larger Departure Scheduler box.

This figure outlines some of the decision support functionality that may be needed by the surface Decision Support Tool (DST) to help tower controllers. For example, a Departure Scheduler (DS) may need input from a Noise Restriction Calculator to determine the aircraft's departure time, and the DS may need to iterate a solution with the Taxi Optimization and Deconfliction module before producing a final advisory that a tower controller can use.

The SRP computed the optimal sequence and time to release a flight from the spot, so it was logical to implement the SRP algorithm as a Push-Back Calculator plug-in. The Runway Scheduler (RS) was implemented as a Taxiway Optimizer and Deconfliction plug-in, because it computed the best sequence for departures to takeoff and arrivals to cross a runway. The SMS software has built-in placeholders for the other functionalities such as the Departure Runway Balancer (DRB). For completeness, a white paper describing possible deployment of modular architecture in support of other airport interaction is presented in *Appendix I: Distributed Surface Management Governance Model (DISSEMINATE).*

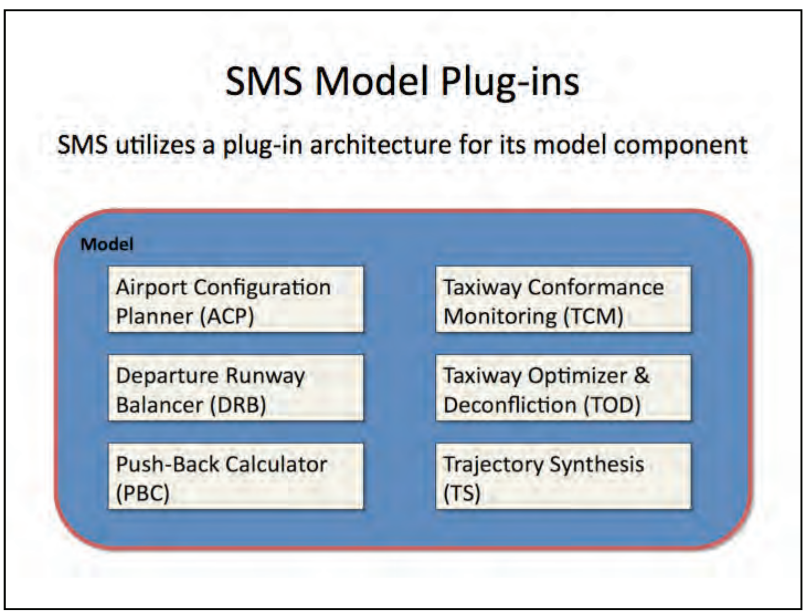

Figure A13: SMS Model Plug-ins.

[7] Surface Management System (SMS): System Administration Guide. Mosaic ATM, Leesburg, VA, 2007.

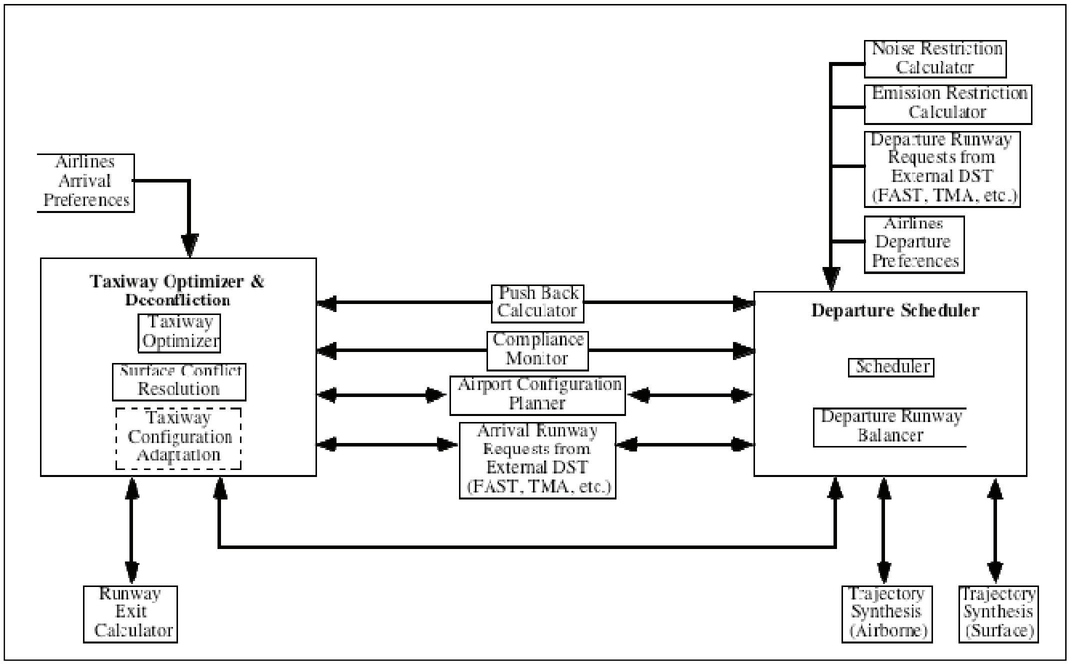

Figure A14: Notional plug-in architecture.

Development of Scheduler Plug-in Modules. SMS is written in Java and is organized into multiple components, CM, CMUI, Model, Client GUI, and CapServer (fig. A3). In support of the SESO research, the SMS software was redesigned to provide a modular plug-in architecture thus providing flexibility for researchers to develop and conduct surface management studies. This section describes in some detail the development of the two plug-ins modules used in the SARDA tests. The SMS Model component allows for integration of external schedulers via its plug-in architecture.

For SARDA, two algorithms were integrated into the SMS Model: SRP and RS. Both modules are written in C++, whereas SMS development solely uses the Java language. The ATG developer created two separate wrappers, one for the SRP and the other for RS, encapsulating necessary flight data from other SMS subsystems and facilitating data exchange.

Development of SrpPBPlugin. SMS uses a plug-in architecture designed to let users replace any of the SMS default plug-ins with their own custom components. The developers implemented the SARDA wrappers as custom plug-ins for two of the Model's components: Push-Back Calculator (PB) and Taxiway Optimizer and Deconfliction (TOD) (fig. A15). They developed the SrpPBPlugin to manage all the data required by the SRP algorithm and all the data that it returned. The wrapper collected aircraft data from SMS such as position and route, sent this data to SRP via a socket, read back advisory data from SRP, and stored that data into SMS for display on the SMS graphical user interface.

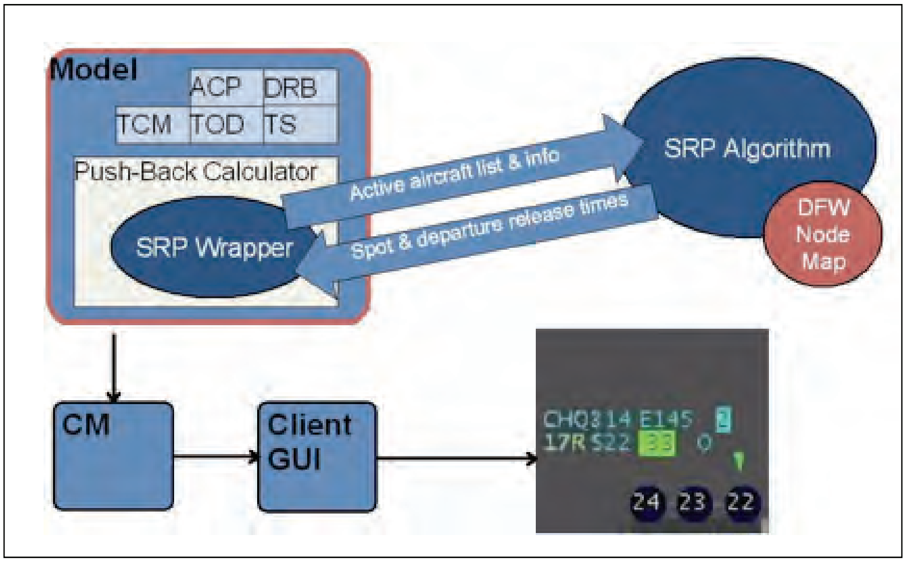

Figure A15: Relationship of SMS Model, plug-in module, algorithm, CM, and GUI.

The calculated data from the scheduler gave the time to first node and time to last node. Time to first node was the SRP-computed ideal time for an aircraft to be released from the spot. The times were sorted to create a sequence for departure aircraft leaving the ramp area. Aircraft with a sequence of one represented the first aircraft to depart. Number two represented the second aircraft in the queue, and so forth. Both the sequence number and the countdown time (in seconds until the aircraft should be released from the spot) were displayed to the controllers on the aircraft's datatag. Figure A15 shows a sample aircraft with a sequence of "2" (on the top line of the datatag) and a countdown time of "33" seconds (bottom line on datatag). A downward pointing arrow is the aircraft icon, which is located right above spot number 22.

Development of RsPlugin. The RsPlugin was designed to handle the requirements of the RS algorithm. It received data from SMS such as a list of aircraft, their positions, whether they were arrivals or departures, and their assigned runway. The flight data were sent to RS via a socket connection. The advisories returned from RS were saved in SMS, and routed and displayed on the GUI. The returned advisory data from the scheduler gave the time to last node.

For aircraft in the departure queue, "last node" indicated the time (relative to the present time, in seconds) that the aircraft should take off. For arrival aircraft, "last node" indicated the time that the aircraft should cross the active departure runway (runway 17R for the SARDA test) to reach the arrival spots. The times to the last node were used to compute the sequence in which arrivals should use the runway. The aircraft that should use the runway first was labeled number one; the next aircraft in sequence labeled number two, etc. For arrival aircraft that were to cross the runway simultaneously, all were grouped together and had the same sequence number. Simultaneous crossings are defined as all crossings that do not have a departure in between them.

Algorithm Integration Within Plug-in Modules. The optimization algorithm programs ran on a remote Linux system. Initially, the scheduling algorithms used the CPLEX[8] solver for computations, but CPLEX was not used for the actual SARDA HITL runs. In a typical operation, the scheduler and the SRP wrapper ran on different host machines. SMS plug-ins communicated with the algorithms over TCP/IP sockets. Data sent from the plug-in modules to the algorithms were formatted into plain text separated by spaces and new lines. This data included which algorithm was called, the number of arrivals and departures in the simulation, departure fix and runway crossing usage, numeric identifiers for aircraft, aircraft simulation activation times, and aircraft taxi routes.

Once the plain text string was created, it was passed to the algorithm via a socket. The algorithm completed its calculations and returned the advisory in a string. This string contained the aircraft identifier and a series of times indicating when the scheduler expected the aircraft to cross each taxi route node. For the SARDA simulation, only the first node and last node were passed. The rest of the route was passed as zeroes and ignored by SMS.

SMS-ATG Software Integration, Lesson Leaned

The SMS-CM had difficulties processing large numbers of CTAS-CAP Server messages. This problem was discovered during SARDA integration testing, where flight track data for up to 100 aircraft was sent through the CTAS-CAP Server interface from ATG to SMS. The result was that the ATG and SMS aircraft displays did not stay synchronized with each other.

The SMS-CAP Server appeared to receive data in a timely manner and queued them for processing. However, SMS was not able to keep up with the queued track messages for more than 65 aircraft. This was determined by turning on queue debug messages in the SMS-CAP server. The debug messages printed out the queue size every 1,000 messages processed. Debug messages were also printed in SMS-CM where it read in the CAP messages, to indicate when 1,000 messages had been processed. After 65 aircraft were active in the simulation, the SMS-CM's CAP message queue was not emptied before the next processing cycle.

The first attempted solution to the problem was to change the socket sleep time from 25 milliseconds to 5 milliseconds per cycle, so that the thread could potentially be accessed more frequently to drain the message queue. This did not resolve the issue, however.

The second solution, which resolved the problem, was to bundle the messages. Originally, the SMS-CAP server would send the data for each aircraft in its own message. By bundling the messages, the current data for all aircraft were gathered into a list, which was sent as a single message to SMS-CM. By handling just a single message instead of N messages, SMS-CM was able to keep up with data updates and the SMS GUI stayed synchronized with ATG.

[8] CPLEX is a high-performance mathematical programming solver for linear programming, mixed integer programming, and quadratic programming. http://www-01.ibm.com/software/integration/optimization/cplex-optimizer/, accessed July 31, 2012.

Roles and Responsibilities

Controllers

The SARDA HITL data runs employed two retired DFW air traffic controllers, one with supervisory experience. The controllers were asked to switch positions (from Ground to Local and vice versa) after each run.

Ground Controller. The ground controller's responsibilities included clearing flights to taxi from spots to departure runway, and to coordinate departures and arrivals leaving and entering the ramp area. The ground controller received advisories from the SRP for the optimal sequence and time to release departures from spots. As the countdown timer falls under 60 seconds, a green background box is superimposed over the timer's text field, which is nominally turquoise in color. From the time the background box turns green, the controller has 60 seconds to push that aircraft from the spot to the Airport Movement Area (AMA) or taxiway. If multiple aircraft are ready to push, the controller gives priority to the lower sequence number. The flexible release window allows the controller opportunity to fit the aircraft around the existing flow of traffic. Examples of datatag and timeline advisories for the ground controller are shown in figures 4 and 5 in the main body of the report, pages 36 and 37, respectively (*Human-in-the-Loop Simulation Evaluation*, *Display Options*).

Local Controller. The local controller's responsibilities involved clearing flights to depart from runway 17R, clearing arrivals to land on 17C (optionally under controller discretion, including which runway exit to take), and clearing arrivals landing on runway 17L to cross 17C and 17R. The local controller received advisories from the RS for the optimal sequence to use 17R for departing flights or crossing arrivals. Unlike the ground controller, the local controller only sees sequence advisories generated by the RS. A typical presentation of the RS information to the local controller is shown in figures 6 and 7 in the main body of the report, pages 38 and 39, respectively. Note the sequence number on the datatag. On the sequence list, the first aircraft for release is displayed at the bottom of the list with later aircraft on top. The local controller should cross all arrivals with the same crossing sequence before launching the next departure.

Both ground and local controllers ensured that the appropriate safety separation between flights was maintained. The controllers viewed and managed aircraft traffic using the SMS GUI map displays. They issued verbal clearances via a digital radio system to pseudo-pilots to move aircraft, and logged the commands via the keyboard for data analysis.

Pseudo-pilots

Manned Pseudo-Pilot. Pseudo-pilots (PPs) were responsible for multiple aircraft including maintaining radio contact with controllers and moving flights as commanded by controllers, either from spots to runways for departures, or from runways to spots for arrivals. They also maintained safe separation between flights. Pilots managed flights in geographically assigned areas on the airport. As a flight left their area of responsibility, they handed off the flight to the neighboring pilot. Conversely, a pilot may receive a handoff from a neighboring pilot. Manned pilots can also send and receive aircraft from the automated pilots (see below). Pilots viewed and moved aircraft traffic using GPS displays (see *Appendix D: Pseudo-Pilot Training Material*).

Automated Pseudo-Pilot. Automated pilots controlled certain parts of the airport. These areas were considered ancillary to the experiment but nonetheless, the aircraft needed to be controlled until they entered or left the research domain. Such areas included movement within the gate and ramp areas, and traffic movement on the west side of the airport. Although SARDA runs focused on the east side of the airport, the scenario had aircraft arriving and departing on the west side of the airport. Automated pilots controlled all west-side movements. These pilots also controlled airborne arrivals heading for runways 17C and 17L. The 17C aircraft was automatically handed off to manned pilots before touchdown. On 17L, it controlled the aircraft to touchdown, rolled, and held short of the 17C, then handed off the aircraft to the manned pilot.

Researchers

Researchers' roles encompassed many areas, including algorithm development, software development, systems integration, human factors, simulation scenario development, and data analysis. Their responsibilities for the SARDA HITL included additional tasks such as training of controllers on SARDA concept and tool, and pseudo-pilots on ATG usage, and observing controllers' and pseudo-pilots' interactions to ensure acceptable workload level by balancing the pseudo-pilot-to-aircraft ratio.

Human factors researchers sat with each controller and noted comments about the simulation system or advisories, trends in controller traffic preferences, and suggestions for improvement.

One researcher acted as a liaison between the Controller/Pilot and Test Engineer Rooms to quickly resolve issues brought up by the research team. Another researcher stayed in the Test Engineer Room to start and stop the simulation software components, monitor their health and performance during the simulation, and archive log files after each run. A third researcher served as technical support to the PP, answering questions and resolving problems. Other researchers in the Briefing Rooms monitored the Researcher SMS station during simulations to observe the simulation progress and the interactions between controller and pilots.

Most of the development and calibration of the tools happened during the initial shakedown and shakedown runs conducted in December 2009 and March 2010, respectively. The April runs relied primarily on the human factors researchers observing, taking notes, distributing questionnaires, and conducting post-run interviews. The rest of the team worked behind the scene to ensure proper system operations and to reduce distraction of the controllers and pilots.

Retired tower controllers from San Francisco International Airport (SFO) were brought in to give the researchers a first glimpse into the implementation of the optimized surface movement concept. Their feedback was used to hone the subsequent procedures. One of the subject matter experts (SMEs) joined the research team and helped with providing training materials for the DFW controllers. The SME acted as a liaison between the researcher and controllers and proved advantageous for both sides.

Simulated Scenario Development

The Air Traffic Generator (ATG) uses text-based scenario files to generate simulated aircraft traffic for the SARDA HITL. Additionally, ATG uses the command list file to issue scripted commands used by the automated pilots, thus controlling the behaviors of the automated aircraft.

The simulation scenario is defined by the arrangement of aircraft specified within the scenario file. The file specifies the activation time and location where aircraft position are to be generated (resembling ground or airborne radar surveillance data), their destination (a gate/spot combination at DFW for arrivals, an airport other than DFW for departures), and an initial set of instructions for the aircraft. These instructions manage the trajectory of the flight and assign ownership of the aircraft to one of the pseudo-pilots. A combination of Matlab scripts and manual adjustments were used to create the aircraft list (see *Appendix E: Scenario Development*).

One of the options in the Matlab scripts determines how aircraft are created in time relative to each other. This feature allows for the creation of simulated peak demand periods within the scenario. Two high-traffic peak times were selected: one very early in the simulation and another toward the middle of the scenario. This type of demand profile allowed researchers the opportunity to observe the system and controller participants' performance and reaction with changing traffic loads. For example, the generated scenario can be crafted to allow time for the system and participants to recover from the first peak, or it can create a sustainably higher traffic load by creating the second peak to occur relatively soon after the first peak.

When aircraft pushed back from the gate, there was a possibility of "collision" if proper temporal separation was not vetted in the development of the scenario file. The aircraft were under automated pilot control in the ramp area, so the only resolution was to ensure that the pushback times for the aircraft were sufficiently far apart that they did not use the same piece of pavement at the same time. This is an order n-squared problem because every gate had to be checked against every other gate. The solution was to create a table that had a matrix of spots and times. The x-axis showed first aircraft pushing back while the y-axis indicated the following aircraft. The values themselves were the minimum times in seconds that the aircraft needed to be separated. This matrix was not symmetrical. When the scenario files were created in Matlab, the Matlab script referenced this file and did not allow any aircraft to be created within the times defined in the matrix.

Another issue discovered in earlier HITLs was that the controllers quickly memorized the scenarios, call signs, and patterns. To prevent the controllers from recognizing previous scenarios, aircraft call signs were renumbered randomly to create five times as many scenarios. There were four unique scenarios, so this change brought the total up to 20 effective scenarios. To save time and reduce manual labor, a program was written to randomize the call sign. Because the airline distribution was fairly accurate, the airline part of the call sign was kept the same. The number of digits in the call sign was also kept the same; however the digits themselves were randomized.

DFW is an American Airlines (AAL) hub and has a substantial footprint at the terminals. Prior analysis using the Surface Operations Data Analysis and Adaptation (SODAA) tool gave the research team the appropriate ratio of AAL flights compared to other airlines at each of the

Terminals (A, C, and E).[9] This was necessary to keep the scenario reflective of current-day carrier distribution and to keep the controllers' focus on the tools and not let the scenario distract them from the desired tasks.

The first pass of this program did not check for call sign number uniqueness. Later, it checked for and resolved call sign number conflicts. There were still some numbers that were close together that were not detected by the system such as AAL261 and AAL621. This was such a rare occurrence that it was addressed on a case-by-case basis.

The aircraft in the initial scenario files were created with sufficient separation between them. However, multiple manual changes were made to the scenario file without regard to maintaining separation. The files had to be modified to preserve the required separation, especially after the landing of a heavy aircraft (i.e., a B772) or a landing that went all the way down to exit M7. This issue was raised by SMEs during earlier simulation runs and was resolved before the data collection runs.

Initially, all arrival aircraft were assigned to the default high-speed exit of M7. However, the SMEs noted that this took unnecessary extra time and would not happen operationally. The practice also caused many backups at M7 if the local controller was not changing the route, and made for sub-optimal planning for the RS. The solution was to select the runway exit depending on the terminal to which the arrival was headed and to automatically route the flight there. Terminal-A-destined aircraft would take exit M3, Terminal C aircraft would take exit M4, and Terminal E aircraft would take exit M7. Exit M6 was used for heavy aircraft destined for Terminals A and C. This solved the problem and reduced the amount of arrivals that the local controller would have to change before landing.

The activation location for arrival aircraft was originally set at 5 nautical miles (nm) upstream from the runway threshold. However, this did not give the controllers enough time to carry out check-in procedures (radio, communication of clearance for landing), so the distance was doubled to 10 nm. The controllers preferred that arrivals be activated at 20 nm out, but the computations required (flight time modeling in SMS) were not feasible within the available integration time frame. RS needed more accurate time estimates than SMS could provide for when arrivals would reach 17R runway crossings. To increase accuracy, the time estimates were manually computed by timing arrivals from activation until they reached the hold short point at 17R for every aircraft type at every runway exit (M3, M4, M6, M7, A, and ER).

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[9] Mosaic ATM Inc.: User's Guide, version 2.7.0, Sept. 9, 2011. http://sodda.mosaicatm.com/sodaa_current/sodaasite/SODAA_User_Guide.pdf

APPENDIX B: SYSTEM STARTUP DETAILS

The Spot and Runway Departure Advisor (SARDA) simulations were conducted at the NASA Ames FutureFlight Central (FFC) airport tower simulator facility. The SARDA simulator consisted of two major software components, the Airspace Traffic Generator (ATG) and the Surface Management System (SMS). The Air Traffic Message Translation Engine (ATMTE), a component of ATG, acts as a middleware or translation component between the two systems.

In summary, ATG's role is to provide the SMS system with simulated radar targets, and provide a platform to host pseudo-pilots, who enter aircraft-control commands to comply with controller's given instructions. The SMS system takes in aircraft track information and provides controllers with aircraft scheduling and sequencing advisories. The controllers then relay aircraft movement instructions to the pseudo-pilots via voice communications.

This appendix catalogues the startup procedures and software components used in support of the April 26th through May 7th, 2010, data collection runs.

Airspace Traffic Generator (ATG) Details

ATG Version 2.16.2

Major ATG software components include:

- Ground Manager (GM)
- Ground Pilot Station (GPS)
- Air Traffic Message Translation Engine (ATMTE)

ATG launch commands: (Linux terminal window)

```
    % cd /vast/users/sarda/atg
    % bin/sim_man –minTaxiSpd 0
    On the commanded pop-up GUI window:
        Select: 'Region' as 'ZFW_LL.region_dir'
        Select: 'Airport' as 'KDFW'
        Select: 'Aircraft List' as 'AprilSim2*.list_data'
        Select: 'Automatic Command Input (Disabled)'; click on 'List'
            Within the List panel, do the following:
            Select: 'Input List Format'; click on 'Sector'
            Select: 'Input List' as 'SARDA_baseline.sect'
            Select: 'Suppress' as 'Yes'
            Click: 'Apply' (Automatic Command Input should show Enabled now), exit
        Select: 'Initialize' or 'Reinitialize'
```

Scenario Files:

The April HITL scenario files were named AprSim2_*.list_data

Training light traffic level: 20 departures, 20 arrivals

Normal traffic level: 30-40 departures, 30-40 arrivals

Heavy traffic level: 50-64 departures, 50-60 arrivals (i.e. AprSim2_50-64.list_data)

Automated Command-Lists Files:
The SARDA simulations used a mixed of automation and pseudo-pilots (in HILT mode) to control aircraft during each run. The automation controlled all aircraft on the west side of DFW, arrivals, departures, and bridge crossing. For the east side, automation controlled aircraft within the terminal ramps (for terminals A, C, and E), east-to-west terminal bridge crossing, airborne traffic (on final for arrivals, and after wheels up for departures), and ground taxi (awaiting) to cross 17C and 17L.

The April HITL simulations used the command file named "*SARDA_baseline.sect*". For completeness, the sample file is included at the end of this section.

Automation also controlled the departures from gates and moved aircraft to the spots. The pseudo-pilot then took control of flights at the spots until the departure runways. After cleared for departure, the pseudo-pilot handed off the aircraft to the automation system, which then removed the aircraft from the simulation, about 15 nm downstream.

Arrivals were automated starting 10 nm out from threshold. After starting the scenario, automation handed off control of the aircraft to the pseudo-pilots, who then determined the runway exit location for runway 17C arrivals. For arrivals on runway 17L, automation determined exit points and taxi route toward runway 17C. The automation handed off aircraft control to the pseudo-pilot after it landed on runway 17C. The pseudo-pilot initiated handoff to automation after taxiing the aircraft to the spot; automation then controlled the aircraft to the gate.

Ground Manager (GM) Details
Version 3.3.5

GM launch commands: (Windows XP icon startup)
Double-click "Shortcut to gm_DFW" on PC desktop to run
/vast/users/sarda/atg/atg/ground/gm_run.bat

Ground Pilot Stations (GPS) Details
Version 3.3.5

Super GPS launch commands used at the FFC: (Windows XP icon startup)
Double-click "Shortcut to PS_DFW_st6" on PC desktop to run
/vast/users/sarda/atg/atg/ground/ps_run.bat to connect GPS to GM on st6 and load the Super GPS display settings

Individual GPS launch commands: (Windows XP icon startup)
Double-click "PPx" icon on pilot PC desktop, where x = pilot station number, to run
/vast/users/sarda/atg/atg/ground/ps_run.bat to connect each Pilot GPS to GM on st6 and load the display settings for each pilot

From the pop-up GUI interface:
Pseudo-Pilot (PP) displays showed specified areas of the airport surface
Pilots clicked on a flight to select it and input a route for it using the mouse or selected a route via the Cmd Keys (keyboard shortcuts)

Pseudo-Pilot (PP) Commands
PP displays had Cmd Keys (keyboard shortcuts) configured for their specified areas of the airport surface. The Cmd Keys window is limited to only six entries. With all six entries in use, there was a desire to have more shortcut keys to support more complex operations. The PP stations were configured to cover the following area:

Arrivals	Departures
	PP1 = departures north
	PP2 = departures south
PP3 = arrivals north	
PP4 = arrivals south	
	PP5 = departure queue
PP6 = arrival exits and runway crossing	

PP1 Cmd Keys definitions:
To 17R Full (from spots 5-7): taxi JY/Ye/J/EFe/EF17R
Handoff to 18L Bridge auto-pilot control (from spots 5-24): HO 124.15/0
To 17R Outer (from spots 15, 22): taxi Ln/EH
To 17R Full (from spots 9-24): taxi Kn/544/Jn/EFe/EF17R
To 17R Inner (from spots 9-24): taxi Kn/EGe/EG17R
To 17R Outer (from spots 9, 11): taxi Kn/Ye/Ln/EH

PP2 Cmd Keys definitions:
To 18L Bridge (from spots 31-53): taxi Kn/Zw/1417
Handoff to PP1 after K8 (ground frequency/PP#): HO 121.65/1
Set nominal taxi speed: speed 15
To 17R Full (from spots 31-53): taxi Kn/544/Jn/EFe/EF17R
To 17R Inner (from spots 31-53): taxi Kn/EGe/EG17R
To 17R Outer (from spots 31-53): taxi Kn/EKe/Ln/EH

PP3 Cmd Keys definitions:
From 17C, M3 exit to gates: taxi K8/Kn/Zw
From 17C, M4 exit to gates: taxi EL/Kn/Zw
Stop aircraft taxi: stop
Continue aircraft taxi: go
Handoff to Terminal A ramp auto-pilot: HO 100.[2-digit gate#]/0, ie HO 100.16/0
Handoff to Terminal C ramp auto-pilot: HO 101.[2-digit gate#]/0, ie HO 101.20/0

PP4 Cmd Keys definitions:
From 17C, M6 exit to gates north of EM: taxi EMw/Kn/Zw
From 17C, M6 exit to gates south of EM: taxi EMw/Ls
From 17L or south bridge to gates: taxi A/Kn/Zw
From 17L to gates: taxi ERw/Kn/Zw
Handoff to PP3 at EL (ground frequency/PP#): HO 121.65/3
Handoff to Terminal E ramp auto-pilot: HO 102.[2-digit gate#]/0, ie HO 102.31/0

PP5 Cmd Keys definitions:

Taxi In Position Hold, 17R Full: taxi EF17R/1187
Taxi In Position Hold, 17R Inner: taxi EG17R/1188
Taxi In Position Hold, 17R Outer: taxi EH17R/1189
Cleared to Depart (handoff to departure auto-pilot): HO 127.5/0
Stop aircraft taxi: stop
Continue aircraft taxi: go

PP6 Cmd Keys definitions:

Take 17C, M3 exit, hold short of 17R: taxi 17C/M3/1342
Take 17C, M4 exit, hold short of 17R: taxi 17C/M4/1324
Take 17C, M6 exit, hold short of 17R: taxi 17C/M6/1327
Take 17C, M7 exit, hold short of 17R: taxi 17C/M7/1295
Handoff to PP3 for M3 and M4 exits (ground frequency/PP#): HO 121.65/3
Handoff to PP4 for M6, M7 exits, 17L arrivals (ground frequency/PP#): HO 121.65/4

Air Traffic Message Translation Engine (ATMTE) Details

Version 1.4

FFC launch command:

```
hostname% cd /vast/users/sarda/atmte
hostname% source ./atmte_env.tcsh
hostname% atmte $VAST_JAVA_PROJECTROOT/atmte_ew.xml
```

Note: TCP/IP configuration was specified in atmte_ew.xml and listed machine names and ports for ATG and SMS

SMS Details

Version 8.3

FFC launch command for SMS core processes:

```
hostname% cd /vast/users/sarda/SMS8.3/sms_run
hostname% ./runcm
hostname% ./runcmui
hostname% ./runmodel
hostname% ./runCap –caphost [linux machine running SMS CM]
```

FFC launch command for ground controller SMS GUI client:

```
hostname%  cd /vast/users/sarda/SMS8.3/sms_run
hostname% ./rungui_baseline_grnd  (for no advisories displayed)
hostname% ./rungui_datatag_grnd  (for advisories displayed in datatags)
hostname% ./rungui_timeline_grnd  (for advisories displayed in timeline)
```

FFC launch command for local controller SMS GUI client:

```
hostname%  cd /vast/users/sarda/SMS8.3/sms_run
hostname% ./rungui_baseline_lcl  (for no advisories displayed)
hostname% ./rungui_datatag_lcl  (for advisories displayed in datatags)
hostname%./rungui_timeline_lcl  (for advisories displayed in timeline)
```

FFC launch command for Researcher SMS GUI client:

```
hostname% cd /vast/users/sarda/SMS8.3/sms_run
hostname% ./rungui_stat
```

SMS/Scheduler Data Interface Details

The TCP/IP data interface between the SMS model wrapper and SRP and RS schedulers looks like the following:

Input (from SMS to SRP/RS)

1st line: Which algorithm SRP or RS: current time in UTC secs
2nd line: Number of departures to be scheduled in this aircraft group
3rd line: Number of arrivals to be scheduled in this aircraft group
4th line: Miles in trail constraints to each departure fix
5th line: Array of simulation time in secs when an aircraft crossed a departure fix or runway crossing:

A time of 9999 means "not set" (no aircraft crossed that fix or rwy xing)
Array slots 0-15 indicate crossing times at fixes
Array slots 16-21 indicate crossing times at 17R for arrivals taking the 17C high speed exits, M3, M4, M6, and M7; and at taxiways A and ER for arrivals from 17L

6th line: Array of aircraft weight classes for the last aircraft that passed each fix and 17R runway crossing
7th and following lines: Aircraft data to be scheduled

The departure fixes and runway crossings are:

Departure Fixes:

LOWGN, BLECO , GRABE, AKUNA, NOBLY, TRISS, SOLDO, CLARE, NELYN, JASPA, ARDIA, DARTZ, FERRA, SLOTT, CEOLA, PODDE

Runway Crossing:

EXIT_ROUTE_M3, EXIT_ROUTE_M4, EXIT_ROUTE_M6, EXIT_ROUTE_M7, EXIT_ROUTE_A, EXIT_ROUTE_ER

The weight classes are:

- SMS weight class string, Heavy, Large, B757, Small
- Equivalent numeric value, 0, 1, 2, 3

The aircraft data line format is (fields separated by one space):

- callsign
- numericAcID
- weightClass
- fixIdx
- predictedTimeToFirstNodeInSimSecs
- acActivationTimeInSimSecs
- taxiRouteNodes

The taxi route format is (fields separated by one space):

- startRouteCode
- listOfTaxiNodes

- endRouteCode
    - Where the starting and ending route codes are one of the following to indicate the aircraft taxi direction and its current location on the airport surface
    - SPOT = "10000" (aircraft is taxiing to/from spot)
    - EAST_RUNWAYS = "10001" (aircraft is taxiing to/from 17R, 17C, 17L)
    - WEST_RUNWAYS = "10002" (aircraft is taxiing to/from 18L, 18R)
    - TAXI_OUT = "10003"" (departure aircraft has left the spot)
    - EASxample, "10000 [taxi nodes] 10001" indicates that the flight is in the ramp area, and its route is from the spot to a runway on the east side of DFW, like 17R

Example:

- SRP : 1272302362
- 25
- 22
- 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
- 9999 31 9999 21 926 322 96 559 9999 9999 9999 9999 9999 9999 9999 9999 592 33 33 420 248 571
- 0 1 0 1 1 1 1 1 0 0 0 0 0 0 0 0 0 1 1 0 1 2 1
- DAL182 3 1 4 10 672 10003 653 652 651 650 649 648 10001
- AAL5254 56 1 5 0 -104 10002 629 630 631 632 633 634 526 303 304 1156 1540 308 1812 736 849 925 210 209 950 208 1002 1030 997 1010 996 1029 1009 358 10000
- AAL580 42 1 7 10 144 10000 350 990 989 1008 988 1033 1007 987 1032 986 1048 941 1819 1043 1042 1041 1040 1005 660 659 658 657 1067 654 653 652 651 650 649 648 10001
- EGF7111 68 1 5 750 -618 10000 350 990 989 1008 988 1033 1007 987 1032 986 1048 941 1819 1043 1042 1041 1040 1005 660 659 658 657 1067 654 653 652 651 650 649 648 10001

Output (from SRP/RS to SMS)

- 1st line: SRP or RS internal return code: Input data time in UTC secs
- 2nd and following lines: Return data with times computed by scheduler

The returned data line format is (fields separated by one space):

- callsign
- numericAcID
- timeToFirstNodeInSimSecs (as many time entries as taxiRouteNodes sent for input)
- timeToLastNodeInSimSecs

The zeros indicate taxi nodes for which times are not computed

Example:

- RETURN MSG: 1 at time: 1272302362
- EGF2871 46 81 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 302
- AAL580 42 24 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 350
- AAL1016 43 97 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 396
- AAL8825 48 221 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 442

- AAL646 40 103 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 488
- AAL737 49 168 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 534
- DAL994 45 139 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 580
- AAL6421 51 327 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 626
- AAL148 58 401 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 672
- DAL1742 50 277 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 718
- DAL413 55 303 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 764
- EGF9214 59 484 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 810
- EGF9497 53 281 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 600

Automated Command List file (sample file): SARDA_baseline.sect

The first column represents the activation time of the commands (located in the third column). The section ownership is listed in the second column. For example, sector- arr17c1, will give the CLA (clear to land) command at 5 seconds in, after taking ownership of the aircraft. This file shows the mapping of commands for all aircraft in Terminals A, C, and E.

```
# Sector File for Automation
# 4/12/10 emcw created for Apr 2010 Baseline HITL (copied from
SARDA_shakedown.sect file)
#
# seconds    Sector     Command

#------ Arrivals on Runway ------#
#------ 17C ------#
5     arr17C1     CLA
20    arr17C1     taxi 17C/M6/1327
30    arr17C1     HO 126.55/6

5     arr17C3     CLA
20    arr17C3     taxi 17C/M3/1342
30    arr17C3     HO 126.55/6

5     arr17C4     CLA
20    arr17C4     taxi 17C/M4/1324
30    arr17C4     HO 126.55/6

5     arr17C6     CLA
20    arr17C6     taxi 17C/M6/1327
30    arr17C6     HO 126.55/6

5     arr17C7     CLA
20    arr17C7     taxi 17C/M7/1295
30    arr17C7     HO 126.55/6

#------ 17L ------#
5     arr17L1     CLA
20    arr17L1     taxi 17L/Q7/ER/HS35C
30    arr17L1     HO 126.55/6
```

```
5     arr17L2     CLA
20    arr17L2     taxi 17L/Q7/ERw/Pe/Aw/1278
30    arr17L2     HO 126.55/6

#------ 18R ------#
5     arr18R1     CLA
20    arr18R1     taxi 18R/E4/WLe/Gn/Ye/HSJY
30    arr18R1     HO 121.65/3

5     arr18R2     CLA
20    arr18R2     taxi 18R/E7/Es/Ae/361
30    arr18R2     HO 121.65/4

#------ 13R ------#
5     arr13R1     CLA
20    arr13R1     taxi 13R/A4/Be/WM/Gn/Ye/HSJY
30    arr13R1     HO 121.65/3

5     arr13R2     CLA
20    arr13R2     taxi 13R/A4/Ae/361
30    arr13R2     HO 121.65/4

#--- Departure Aircraft on Surface ---#
1     SURF1 taxi K/EG/EG17R
5     SURF1 HO 126.55/1

1     SURF2 taxi K/EF/EF17R
5     SURF2 HO 126.55/1

1     SURF3 taxi K/EH/EH17R
5     SURF3 HO 126.55/1

1     SURF4 HO 124.15/0

1     SURF5 taxi Kn/spot10
5     SURF5 HO 121.65/3

1     SURF6 taxi M4/1344
5     SURF6 HO 126.55/3

1     SURF7 taxi Bw/Kn/spot10
5     SURF7 HO 121.65/3

1     SURF8 taxi ELw/Kn/spot14
5     SURF8 HO 121.65/3

# >>> Arrivals on taxi to SPOTs
2     taxiK2S10   taxi Kn/spot10
4     taxiK2S10   speed 15
5     taxiK2S10   HO 121.65/3

#--- Gate Automation (Departures)------#
#---------- Terminal A ----------------#
1     Dgatea9     taxi pba9
5     Dgatea9     HO 200.07/0

1     Dgatea10    taxi pba10
5     Dgatea10    HO 200.07/0

1     Dgatea11    taxi pba11
```

```
5     Dgatea11    HO 200.07/0

1     Dgatea12    taxi pba12
5     Dgatea12    HO 200.07/0

1     Dgatea13    taxi pba13
5     Dgatea13    HO 200.07/0

1     Dgatea14    taxi pba14
5     Dgatea14    HO 200.07/0

1     Dgatea15    taxi pba15
5     Dgatea15    HO 200.07/0

1     Dgatea16    taxi pba16
5     Dgatea16    HO 200.09/0

1     Dgatea17    taxi pba17
5     Dgatea17    HO 200.09/0

1     Dgatea18    taxi pba18
5     Dgatea18    HO 200.09/0

1     Dgatea19    taxi pba19
5     Dgatea19    HO 200.09/0

1     Dgatea20    taxi pba20
5     Dgatea20    HO 200.11/0

1     Dgatea21    taxi pba21
5     Dgatea21    HO 200.11/0

1     Dgatea22    taxi pba22
15    Dgatea22    taxi tae
35    Dgatea22    HO 200.11/0

1     Dgatea23    taxi pba23
5     Dgatea23    HO 200.15/0

1     Dgatea24    taxi pba24
5     Dgatea24    HO 200.15/0

1     Dgatea25    taxi pba25
5     Dgatea25    HO 200.15/0

1     Dgatea26    taxi pba26
5     Dgatea26    HO 200.15/0

1     Dgatea28    taxi pba28
5     Dgatea28    HO 200.15/0

1     Dgatea29    taxi pba29
5     Dgatea29    HO 200.15/0

1     Dgatea33    taxi pba33
5     Dgatea33    HO 200.22/0

1     Dgatea34    taxi pba34
5     Dgatea34    HO 200.22/0

1     Dgatea35    taxi pba35
```

```
5     Dgatea35   HO 200.22/0

1     Dgatea36   taxi pba36
5     Dgatea36   HO 200.22/0

1     Dgatea37   taxi pba37
5     Dgatea37   HO 200.22/0

1     Dgatea38   taxi pba38
5     Dgatea38   HO 200.22/0

1     Dgatea39   taxi pba39
5     Dgatea39   HO 200.22/0

#---------- Terminal C ----------------#
1     Dgatec2    taxi pbc2
5     Dgatec2    HO 200.22/0

1     Dgatec3    taxi pbc3
5     Dgatec3    HO 200.22/0

1     Dgatec4    taxi pbc4
5     Dgatec4    HO 200.22/0

1     Dgatec6    taxi pbc6
5     Dgatec6    HO 200.22/0

1     Dgatec7    taxi pbc7
5     Dgatec7    HO 200.22/0

1     Dgatec8    taxi pbc10
5     Dgatec8    HO 200.22/0

1     Dgatec10   taxi pbc12
5     Dgatec10   HO 200.22/0

1     Dgatec11   taxi pbc11
5     Dgatec11   HO 200.31/0

1     Dgatec12   taxi pbc12
5     Dgatec12   HO 200.31/0

1     Dgatec14   taxi pbc14
5     Dgatec14   HO 200.31/0

1     Dgatec15   taxi pbc15
5     Dgatec15   HO 200.31/0

1     Dgatec16   taxi pbc19
5     Dgatec16   HO 200.31/0

1     Dgatec17   taxi pbc17
5     Dgatec17   HO 200.33/0

1     Dgatec19   taxi pbc19
5     Dgatec19   HO 200.33/0

1     Dgatec20   taxi pbc22
5     Dgatec20   HO 200.33/0

1     Dgatec21   taxi pbc24
```

```
5     Dgatec21    HO 200.33/0

1     Dgatec22    taxi pbc22
5     Dgatec22    HO 200.35/0

1     Dgatec24    taxi pbc24
5     Dgatec24    HO 200.35/0

1     Dgatec25    taxi pbc25
5     Dgatec25    HO 200.35/0

1     Dgatec26    taxi pbc26
5     Dgatec26    HO 200.35/0

1     Dgatec27    taxi pbc27
5     Dgatec27    HO 200.37/0

1     Dgatec28    taxi pbc28
5     Dgatec28    HO 200.37/0

1     Dgatec29    taxi pbc29
5     Dgatec29    HO 200.37/0

1     Dgatec30    taxi pbc30
5     Dgatec30    HO 200.37/0

1     Dgatec31    taxi pbc31
5     Dgatec31    HO 200.37/0

1     Dgatec32    taxi pbc32
5     Dgatec32    HO 200.42/0

1     Dgatec33    taxi pbc33
5     Dgatec33    HO 200.42/0

1     Dgatec35    taxi pbc35
5     Dgatec35    HO 200.42/0

1     Dgatec36    taxi pbc36
5     Dgatec36    HO 200.42/0

1     Dgatec37    taxi pbc37
5     Dgatec37    HO 200.42/0

1     Dgatec39    taxi pbc39
5     Dgatec39    HO 200.42/0

#---------- Terminal E ----------------#
1     Dgatee2     taxi pbe2
5     Dgatee2     HO 200.42/0

1     Dgatee3     taxi pbe3
5     Dgatee3     HO 200.42/0

1     Dgatee4     taxi pbe4
5     Dgatee4     HO 200.42/0

1     Dgatee5     taxi pbe5
5     Dgatee5     HO 200.42/0

1     Dgatee6     taxi pbe6
```

5	Dgatee6	HO 200.42/0
1	Dgatee8	taxi pbe10
5	Dgatee8	HO 200.42/0
1	Dgatee9	taxi pbe9
5	Dgatee9	HO 200.45/0
1	Dgatee10	taxi pbe10
45	Dgatee10	HO 200.45/0
1	Dgatee11	taxi pbe11
5	Dgatee11	HO 200.45/0
1	Dgatee13	taxi pbe13
5	Dgatee13	HO 200.45/0
1	Dgatee14	taxi pbe14
5	Dgatee14	HO 200.45/0
1	Dgatee15	taxi pbe17
5	Dgatee15	HO 200.45/0
1	Dgatee16	taxi pbe16
5	Dgatee16	HO 200.47/0
1	Dgatee17	taxi pbe19
5	Dgatee17	HO 200.47/0
1	Dgatee18	taxi pbe18
5	Dgatee18	HO 200.47/0
1	Dgatee19	taxi pbe19
5	Dgatee19	HO 200.47/0
1	Dgatee20	taxi pbe20
5	Dgatee20	HO 200.47/0
1	Dgatee21	taxi pbe21
5	Dgatee21	HO 200.47/0
1	Dgatee31	taxi pbe31
5	Dgatee31	HO 200.47/0
1	Dgatee32	taxi pbe32
5	Dgatee32	HO 200.47/0
1	Dgatee33	taxi pbe33
5	Dgatee33	HO 200.47/0
1	Dgatee34	taxi pbe34
5	Dgatee34	HO 200.47/0
1	Dgatee35	taxi pbe35
5	Dgatee35	HO 200.47/0
1	Dgatee36	taxi pbe36
5	Dgatee36	HO 200.47/0
1	Dgatee37	taxi pbe37
5	Dgatee37	HO 200.47/0

```
1     Dgatee38   taxi pbe38
5     Dgatee38   HO 200.47/0

#----------- Spots -----------------#
15    Dspot7      taxi  ta spot7
16    Dspot7     HO 121.65/1

15    Dspot9      taxi  ta spot9
16    Dspot9     HO 121.65/1

15    Dspot11      taxi  ta spot11
16    Dspot11    HO 121.65/1

15    Dspot15      taxi  ta spot15
16    Dspot15    HO 121.65/1

15    Dspot22      taxi  s22e
16    Dspot22    HO 121.65/1

# emcw 4/15/10: Changed from PP1 to PP2
15    Dspot31     taxi  tc spot31
16    Dspot31    HO 121.65/2

# emcw 4/15/10: Changed from PP1 to PP2
15    Dspot33      taxi  tc spot33
16    Dspot33    HO 121.65/2

15    Dspot35      taxi  tc spot35
16    Dspot35    HO 121.65/2

15    Dspot37      taxi  tc spot37
16    Dspot37    HO 121.65/2

15    Dspot42      taxi  s42e
16    Dspot42    HO 121.65/2

15    Dspot45     taxi  te spot45
16    Dspot45    HO 121.65/2

15    Dspot47      taxi  te spot47
16    Dspot47    HO 121.65/2


#---- Gate Automation (Arrivals)-------#
#---------- Terminal A ----------------#
1     Agatea9    taxi Ze JYs ta gatea9
2     Agatea9    taxi Kn Zw JYs ta gatea9
3     Agatea9    taxi ta gatea9
180   Agatea9    remove

1     Agatea10   taxi ta gatea10
180   Agatea10   remove

1     Agatea11   taxi ta gatea11
180   Agatea11   remove

1     Agatea12   taxi ta gatea12
180   Agatea12   remove

1     Agatea13   taxi ta gatea13
```

```
180   Agatea13    remove

1     Agatea14    taxi ta gatea14
180   Agatea14    remove

1     Agatea15    taxi ta gatea15
180   Agatea15    remove

1     Agatea16    taxi ta gatea16
180   Agatea16    remove

1     Agatea17    taxi ta gatea17
180   Agatea17    remove

1     Agatea18    taxi ta gatea18
180   Agatea18    remove

1     Agatea19    taxi ta gatea19
180   Agatea19    remove

1     Agatea20    taxi ta gatea20
180   Agatea20    remove

1     Agatea21    taxi ta gatea21
180   Agatea21    remove

1     Agatea22    taxi ta gatea22
180   Agatea22    remove

1     Agatea23    taxi ta gatea23
180   Agatea23    remove

1     Agatea24    taxi ta gatea24
180   Agatea24    remove

1     Agatea25    taxi ta gatea25
180   Agatea25    remove

1     Agatea26    taxi ta gatea26
180   Agatea26    remove

1     Agatea28    taxi s24w gatea28
180   Agatea28    remove

1     Agatea29    taxi s24w gatea29
180   Agatea29    remove

1     Agatea33    taxi ta gatea33
180   Agatea33    remove

1     Agatea34    taxi s24w gatea34
180   Agatea34    remove

1     Agatea35    taxi s24w gatea35
180   Agatea35    remove

1     Agatea36    taxi s24w gatea36
180   Agatea36    remove

1     Agatea37    taxi s24w gatea37
180   Agatea37    remove
```

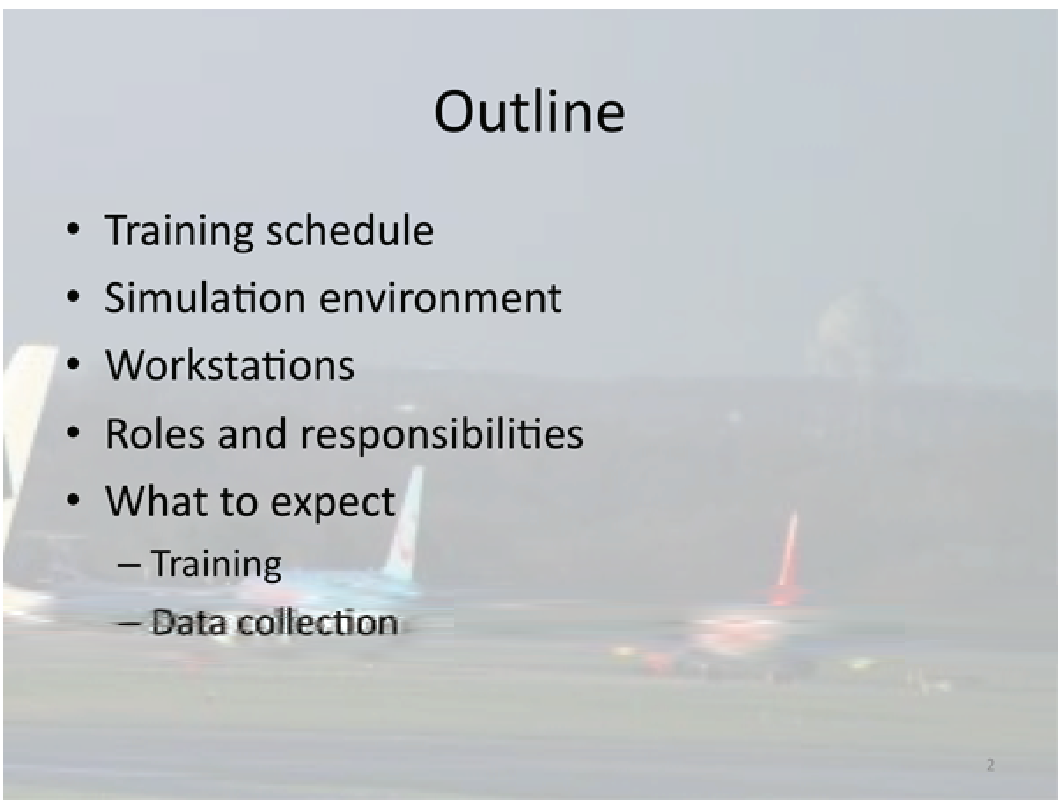
```
1     Agatea38    taxi s24w gatea38
180   Agatea38    remove

1     Agatea39    taxi s24w gatea39
180   Agatea39    remove

#---------- Terminal C ----------------#
1     Agatec2     taxi s24w gatec2
180   Agatec2     remove

1     Agatec3     taxi s24w gatec3
180   Agatec3     remove

1     Agatec4     taxi s24w gatec4
180   Agatec4     remove

1     Agatec6     taxi s24w gatec6
180   Agatec6     remove

1     Agatec7     taxi s24w gatec7
180   Agatec7     remove

1     Agatec8     taxi s24w gatec8
180   Agatec8     remove

1     Agatec10    taxi s24w gatec10
180   Agatec10    remove

1     Agatec11    taxi tc gatec11
180   Agatec11    remove

1     Agatec12    taxi tc gatec12
180   Agatec12    remove

1     Agatec14    taxi tc gatec14
180   Agatec14    remove

1     Agatec15    taxi tc gatec15
180   Agatec15    remove

1     Agatec16    taxi tc gatec16
180   Agatec16    remove

1     Agatec17    taxi tc gatec17
180   Agatec17    remove

1     Agatec19    taxi tc gatec19
180   Agatec19    remove

1     Agatec20    taxi tc gatec20
180   Agatec20    remove

1     Agatec21    taxi tc gatec21
180   Agatec21    remove

1     Agatec22    taxi tc gatec22
180   Agatec22    remove

1     Agatec24    taxi tc gatec24
180   Agatec24    remove
```

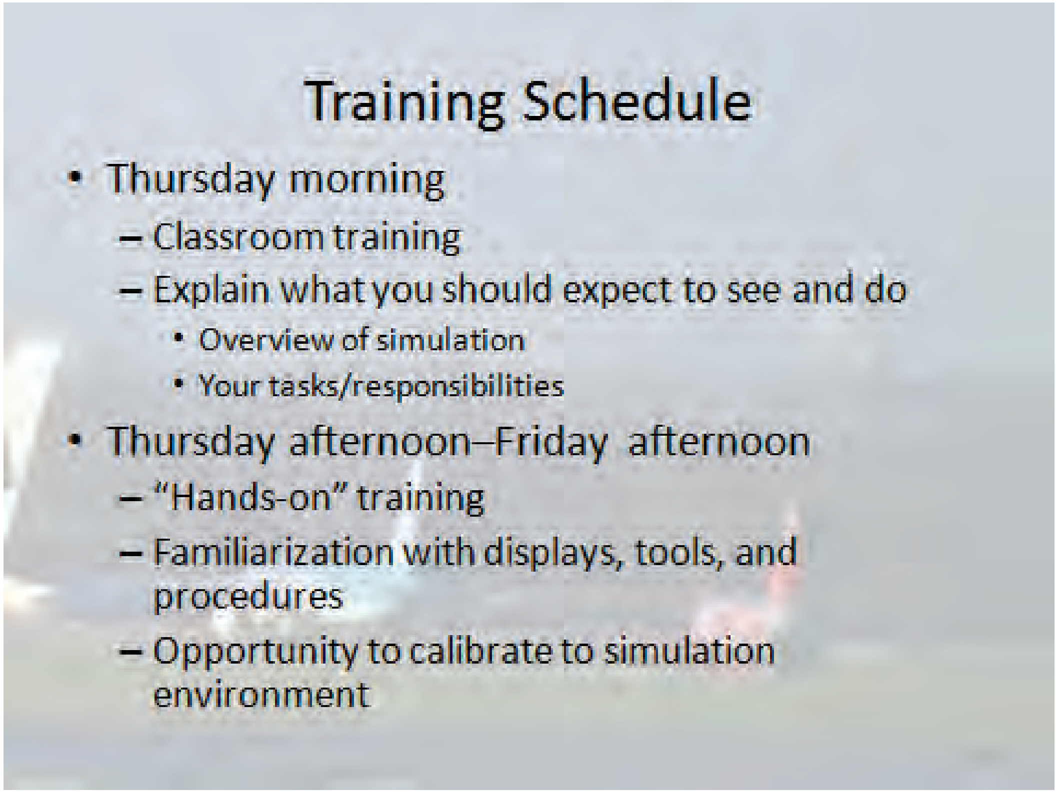
```
1     Agatec25    taxi tc gatec25
180   Agatec25    remove

1     Agatec26    taxi tc gatec26
180   Agatec26    remove

1     Agatec27    taxi tc gatec27
180   Agatec27    remove

1     Agatec28    taxi tc gatec28
180   Agatec28    remove

1     Agatec29    taxi tc gatec29
180   Agatec29    remove

1     Agatec30    taxi tc gatec30
180   Agatec30    remove

1     Agatec31    taxi s44w gatec31
180   Agatec31    remove

1     Agatec32    taxi s44w gatec32
180   Agatec32    remove

1     Agatec33    taxi s44w gatec33
180   Agatec33    remove

1     Agatec35    taxi s44w gatec35
180   Agatec35    remove

1     Agatec36    taxi s44w gatec36
180   Agatec36    remove

1     Agatec37    taxi s44w gatec37
180   Agatec37    remove

1     Agatec39    taxi s44w gatec39
180   Agatec39    remove

#---------- Terminal E ----------------#
1     Agatee2     taxi s44w gatee2
180   Agatee2     remove

1     Agatee3     taxi s44w gatee3
180   Agatee3     remove

1     Agatee4     taxi s44w gatee4
180   Agatee4     remove

1     Agatee5     taxi s44w gatee5
180   Agatee5     remove

1     Agatee6     taxi s44w gatee6
180   Agatee6     remove

1     Agatee8     taxi s44w gatee8
180   Agatee8     remove

1     Agatee9     taxi s44w gatee9
180   Agatee9     remove
```

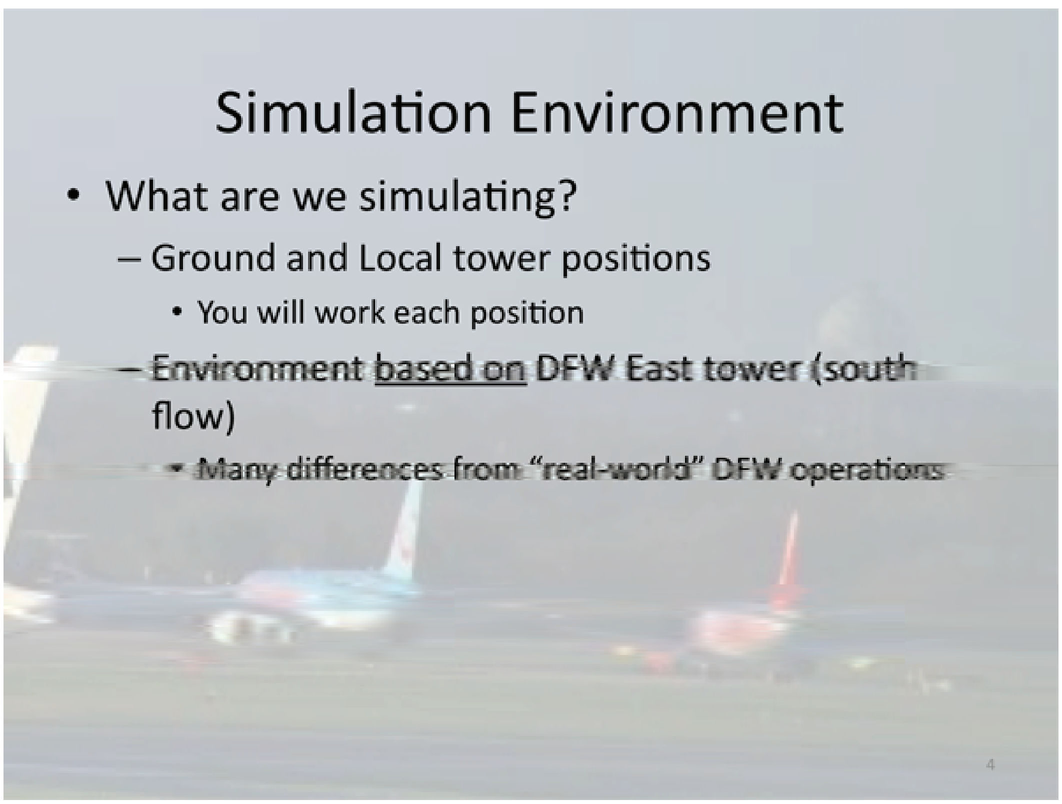
```
1     Agatee10    taxi s44w gatee10
180   Agatee10    remove

1     Agatee11    taxi te gatee11
180   Agatee11    remove

1     Agatee13    taxi te gatee13
180   Agatee13    remove

1     Agatee14    taxi te gatee14
180   Agatee14    remove

1     Agatee15    taxi te gatee15
180   Agatee15    remove

1     Agatee16    taxi te gatee16
180   Agatee16    remove

1     Agatee17    taxi te gatee17
180   Agatee17    remove

1     Agatee18    taxi te gatee18
180   Agatee18    remove

1     Agatee19    taxi te gatee19
180   Agatee19    remove

1     Agatee20    taxi te gatee20
180   Agatee20    remove

1     Agatee21    taxi te gatee21
180   Agatee21    remove

1     Agatee31    taxi te gatee31
180   Agatee31    remove

1     Agatee32    taxi 190 gatee32
180   Agatee32    remove

1     Agatee33    taxi 190 gatee33
180   Agatee33    remove

1     Agatee34    taxi 190 gatee34
180   Agatee34    remove

1     Agatee35    taxi 190 gatee35
180   Agatee35    remove

1     Agatee36    taxi 190 te gatee36
180   Agatee36    remove

1     Agatee37    taxi 190 te gatee37
180   Agatee37    remove

1     Agatee38    taxi 190 te gatee38
180   Agatee38    remove


#---- Departure Aircraft to 18L ----#
1     towerw      taxi Kn/Zw/Gn/WG/18L/cld
```

```
2     towerw      taxi Zw/Gn/WG/18L/cld # >>> Arrivals on taxi to SPOTs
2     taxiK2S10   taxi K/SPOT10
4     taxiK2S10   speed 15
800   towerw      remove

#---- Departure Aircraft on 17R ----#

1     towere2     taxi 17Rs/cld
2     towere2     cld
400   towere2     remove

#---- Southbound Aircraft, South Bound (SB) ----#

1     towereSB    taxi 17Rs/cld
2     towereSB    cld
400   towereSB    remove

#---- Southbound Aircraft, EastBound (EB)_ ----#

1     towereEB    taxi 17Rs/cld
2     towereEB    cld
80    towereEB    heading 165
400   towereEB    remove
```

APPENDIX C: CONTROLLER TRAINING MATERIAL



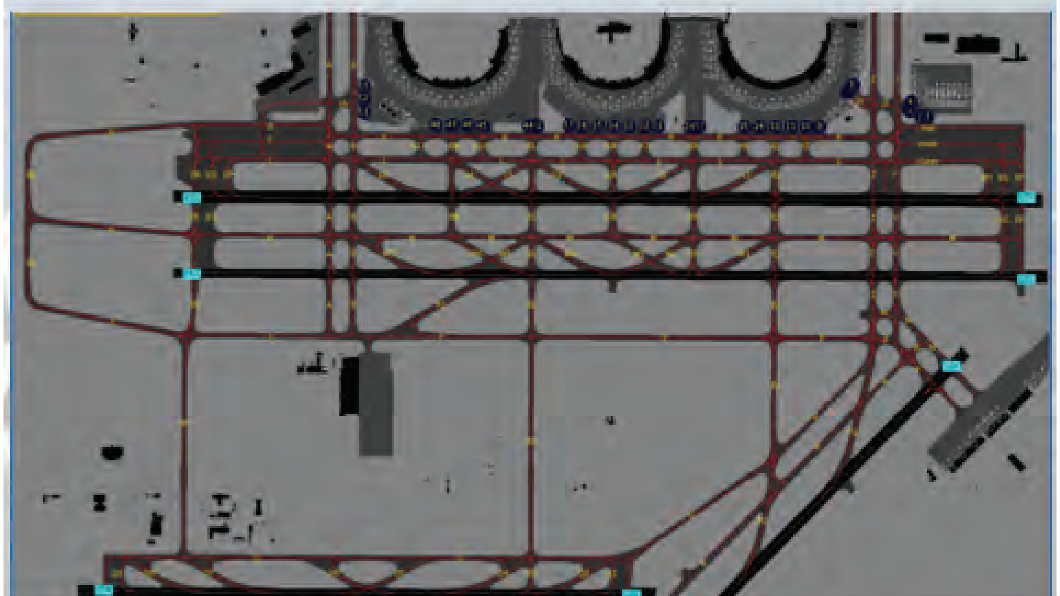

Training Schedule
• Thursday morning
– Classroom training
– Explain what you should expect to see and do
• Overview of simulation
• Your tasks/responsibilities
• Thursday afternoon–Friday afternoon
– "Hands-on" training
– Familiarization with displays, tools, and procedures
– Opportunity to calibrate to simulation environment

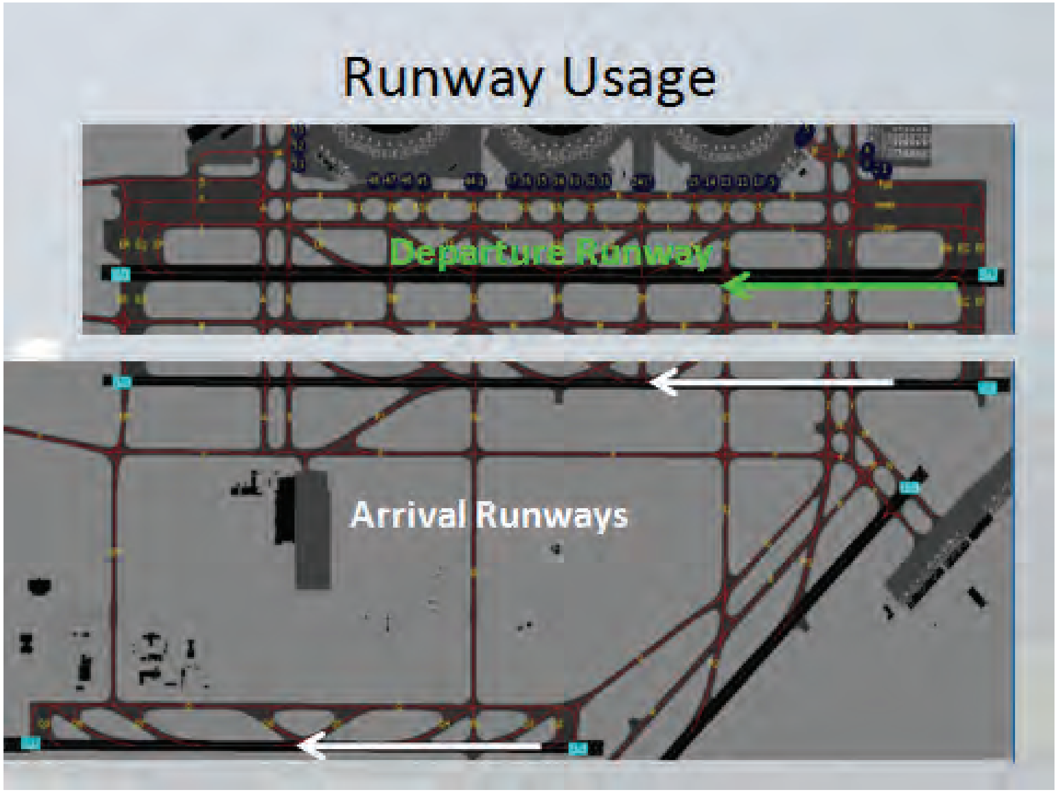

Simulation Environment
• What are we simulating?
– Ground and Local tower positions
• You will work each position
– Environment based on DFW East tower (south flow)
• Many differences from "real-world" DFW operations
4

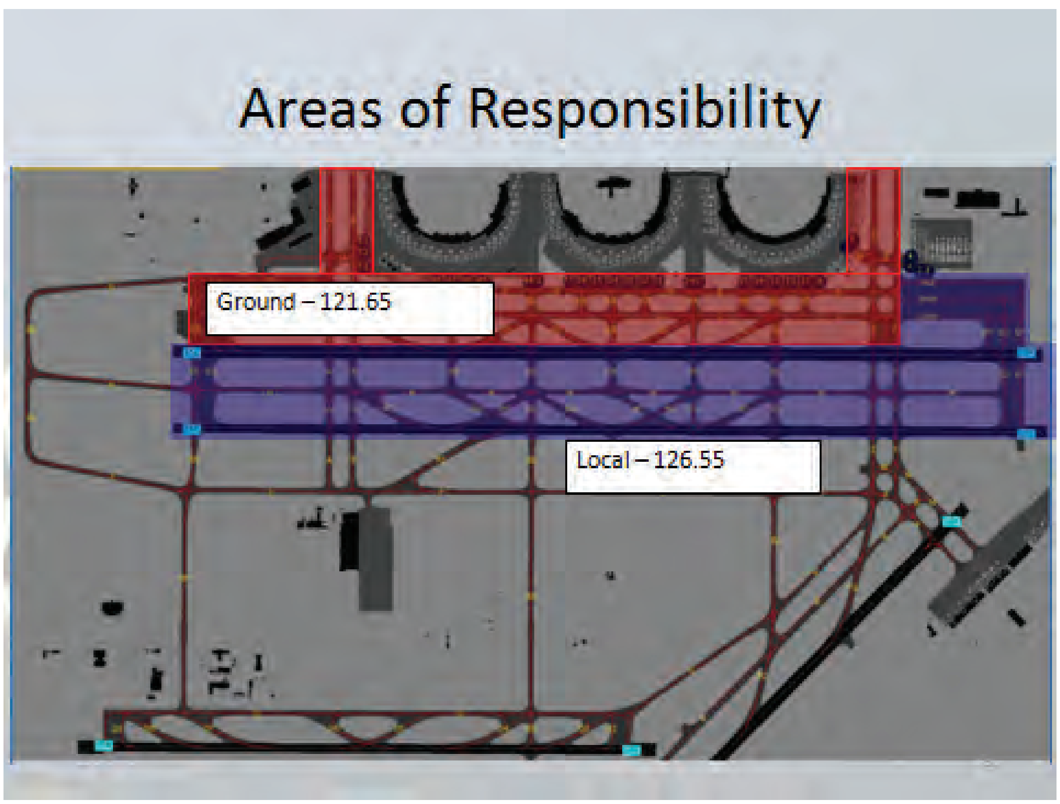
Differences From “Real-World” DFW

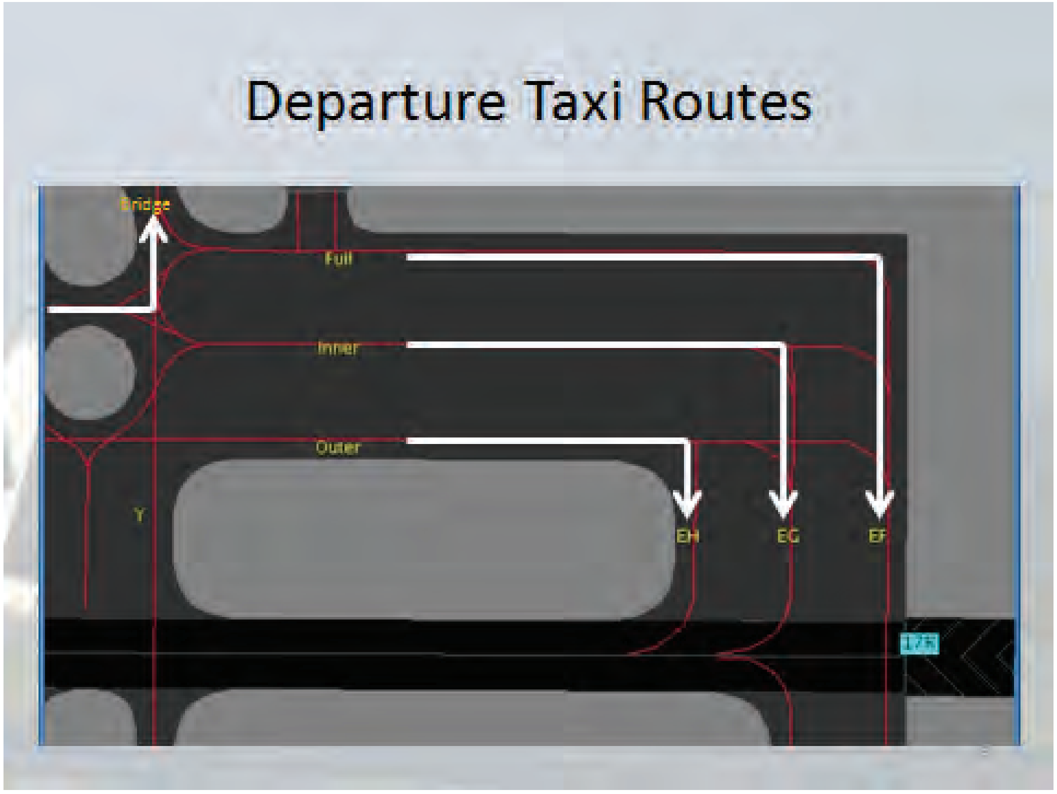
- No “out-the-window” view
  - Overhead-view map displays
- No flight strips
  - Additional info in data tags
- Taxiway and runway restrictions
- Local East 2 controller automated
- Arrivals have preassigned runway exits (appear in datatags)
  - Partial compensation for no out-the-window view
  - You can reassign
- Separation benchmarks for departures
  - We will calibrate these during hands-on training
- Keyboard/mouse data-entry procedures for departures
- Pseudo-pilots
  - Each controlling multiple aircraft
  - Have a restricted range of actions they can take (e.g., no go-arounds)
- No weather (assume light to moderate winds)
- No off-nominal situations or emergencies (not planned anyway!)
- Sometimes, an advisory tool (SRP and RS) will be telling you what to do
- Sometimes, your goals will be different than in today’s real-world operations

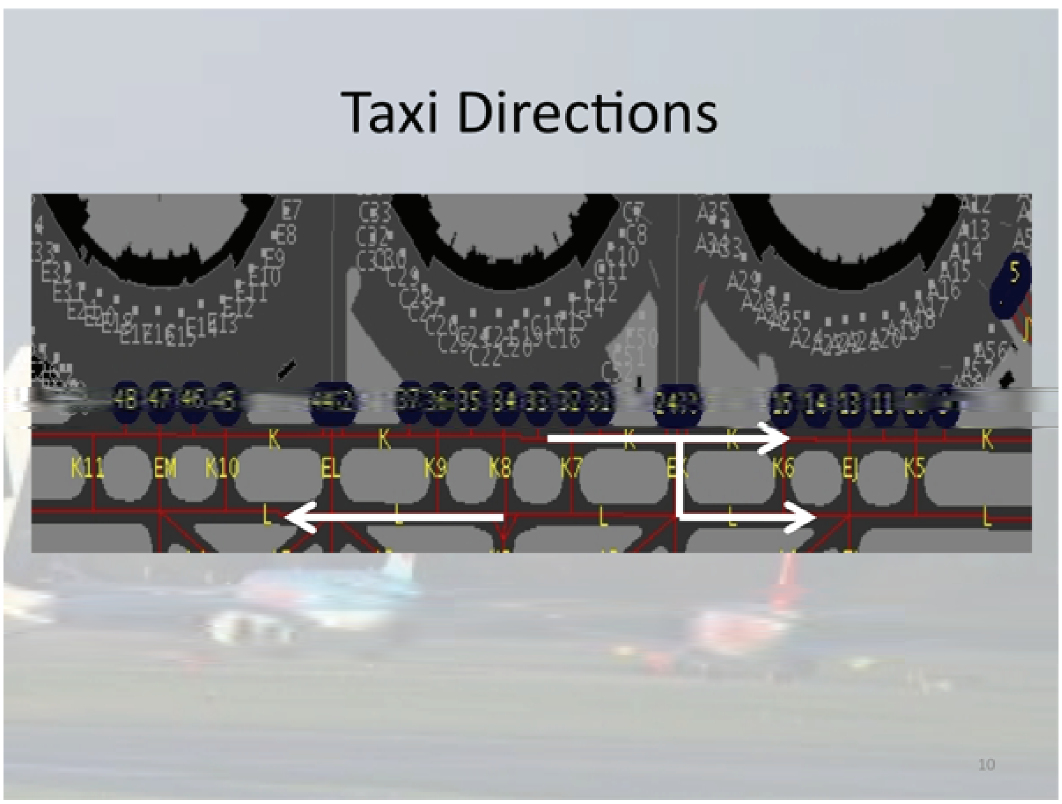
Airport Layout

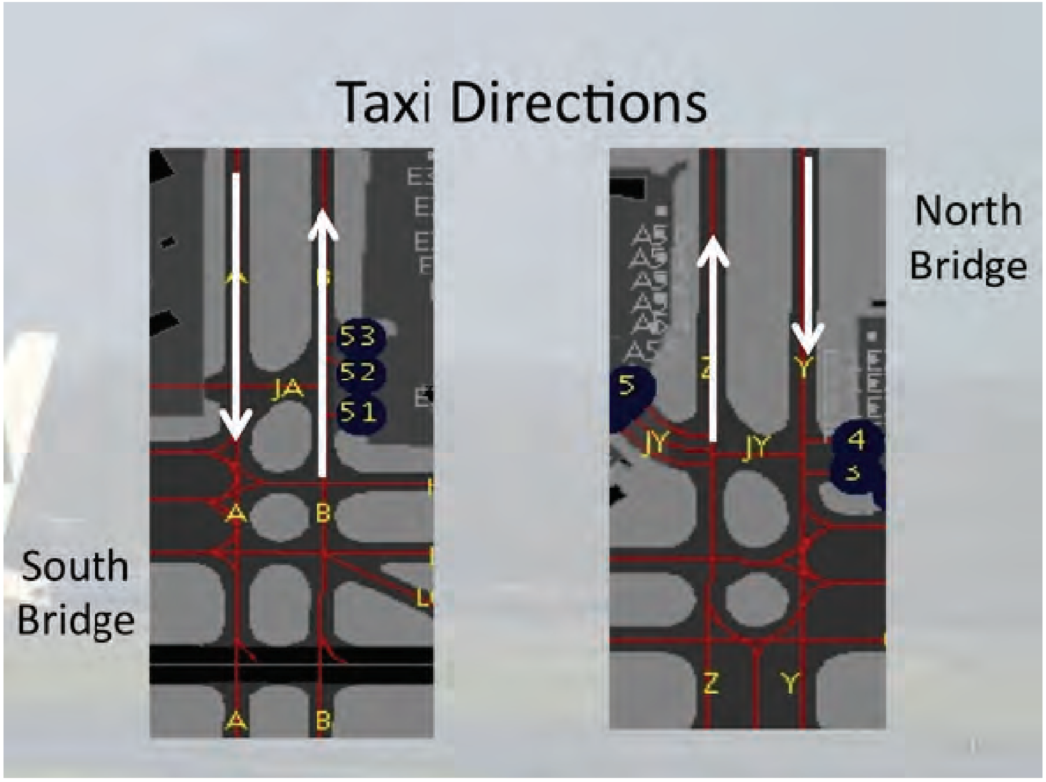


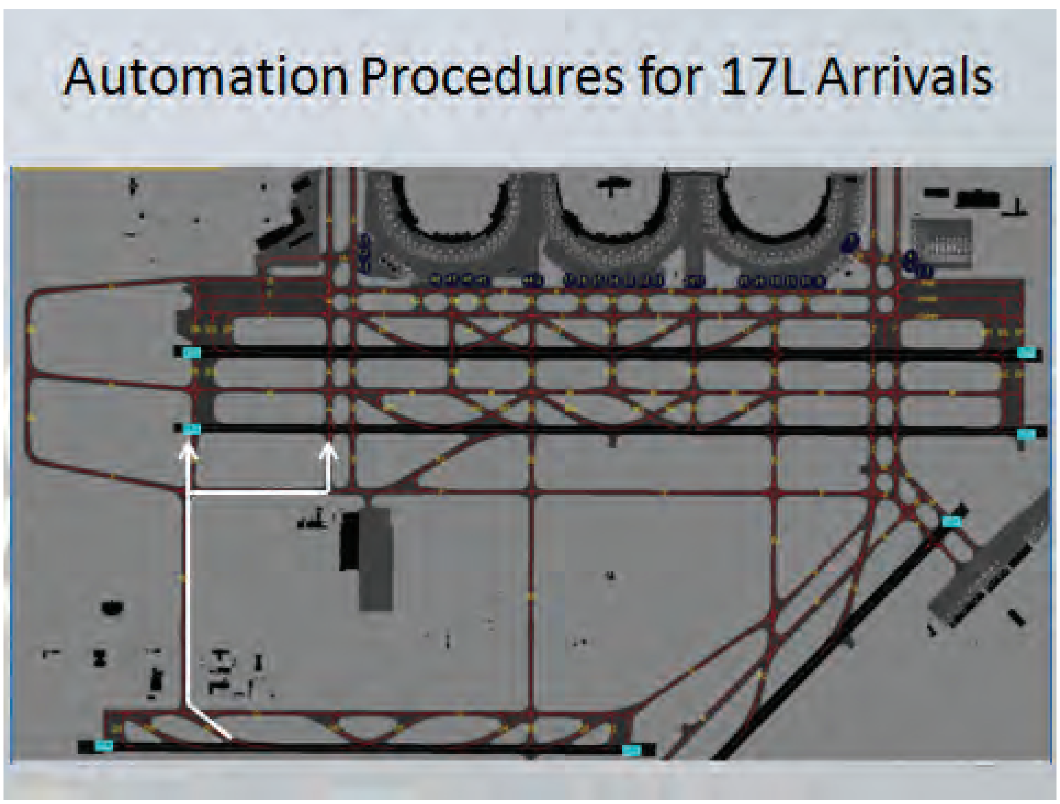

Runway Usage
Departure Runway
Arrival Runways


Areas of Responsibility
Ground – 121.65
Local – 126.55


Departure Taxi Routes
Bridge
Full
Inner
Outer
Y
EH
EG
EF
17R


Taxi Directions
K11
EM
K10
EL
K9
K8
K7
K6
EJ
K5
K
L
10


Taxi Directions
South
Bridge
North
Bridge
JA
53
52
51
A
B
5
4
JY
Z
Y


Automation Procedures for 17L Arrivals

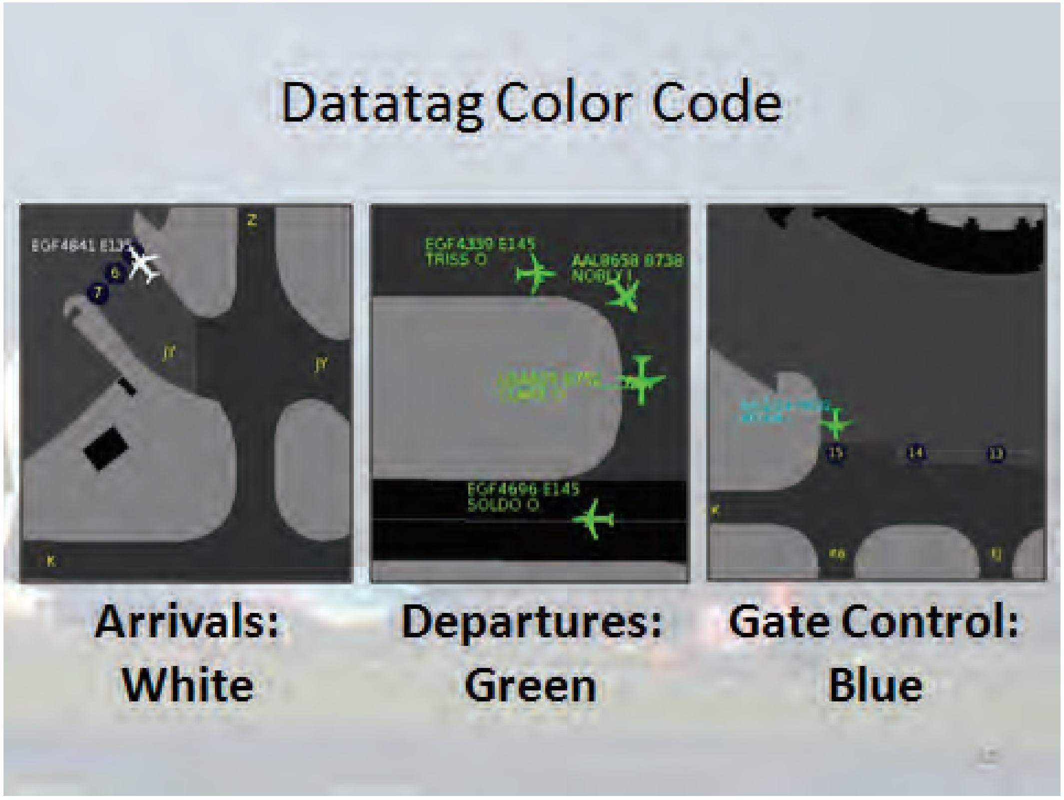
Arrivals: Preassigned Runway Exits

Aircraft Icons

LARGE
(and 757)

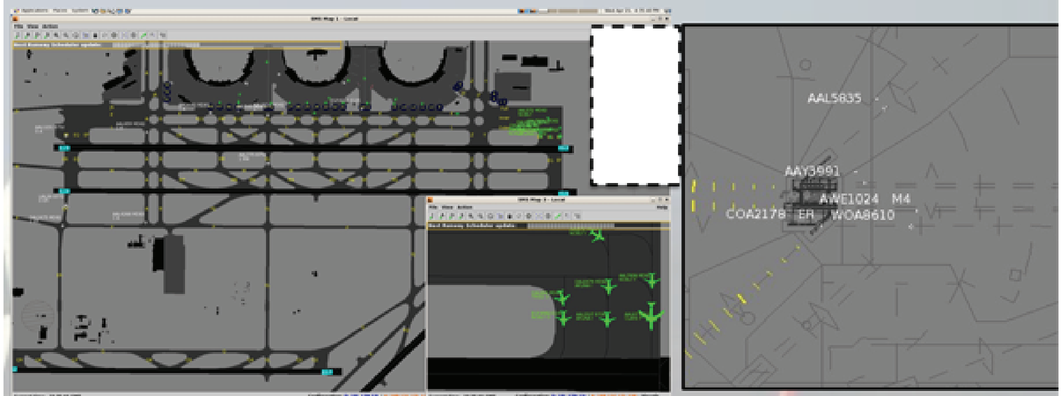
HEAVY

14


Datatag Color Code
EGF4641 E135
EGF4339 E145
TRISS O
AAL8658 B738
EGF4696 E145
SOLDO O
Arrivals:
White
Departures:
Green
Gate Control:
Blue


Ground Workstation
16

Local Workstation

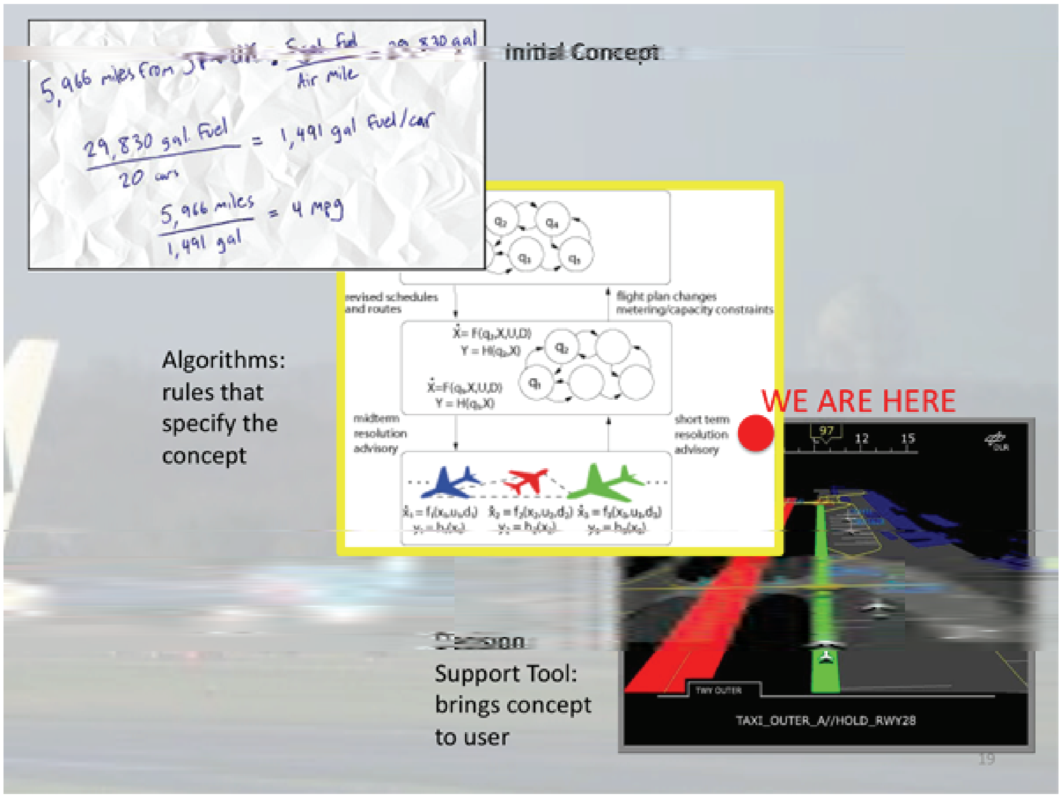


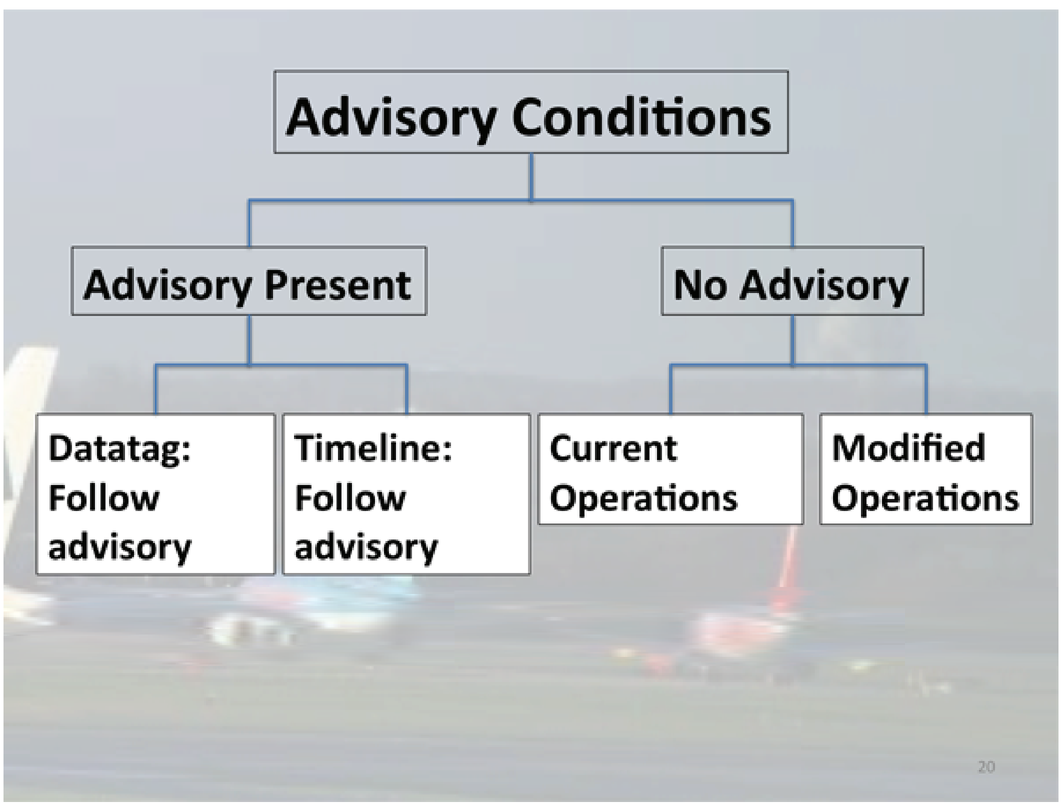
17

Roles and Responsibilities

- Help us evaluate our operational concept/algorithms
  – Meter departure aircraft from the spot instead of saturating the departure queue
  – Minimize taxi time from spot to queue
  – Reduce taxi delay to reduce fuel, emissions
  – Increase throughput
- Your participation enables us to collect data
  – From the simulation computers
  – From observers watching you run traffic
  – From questionnaires and briefings

18

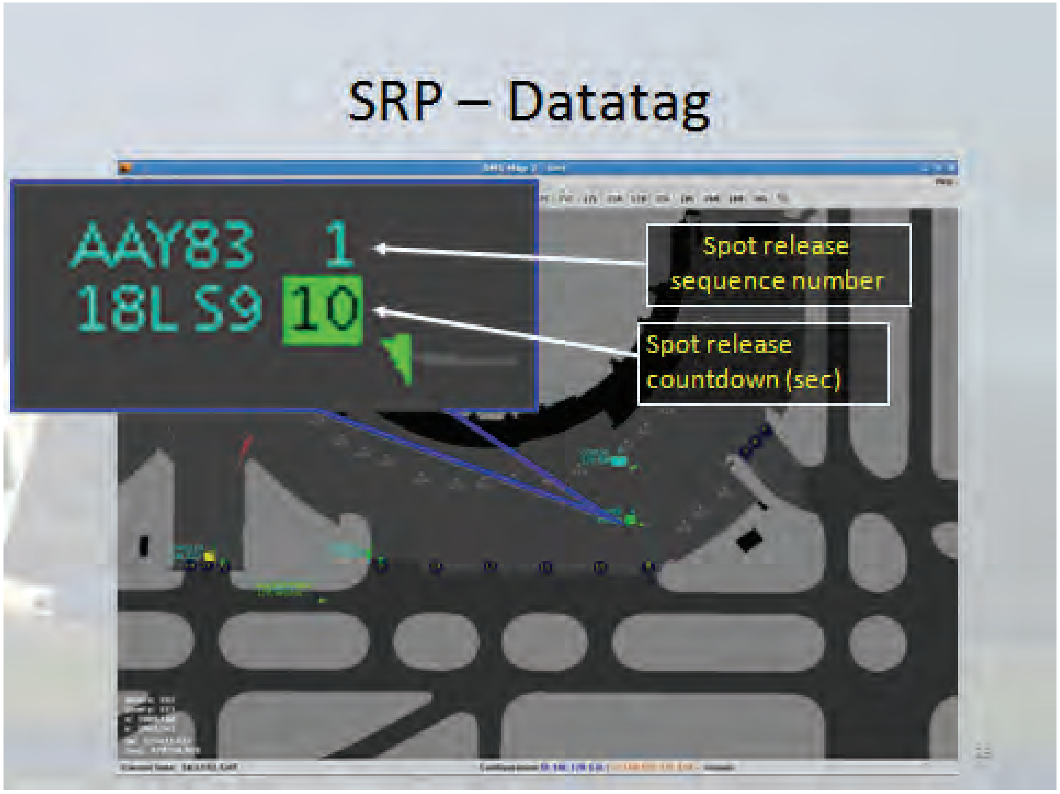

29,830 gal. Fuel / 20 cars = 1,491 gal Fuel/car
5,966 miles / 1,491 gal = 4 mpg
Initial Concept
revised schedules and routes
flight plan changes metering/capacity constraints
midterm resolution advisory
short term resolution advisory
Algorithms: rules that specify the concept
WE ARE HERE
Decision Support Tool: brings concept to user
TAXI_OUTER_A//HOLD_RWY28
19

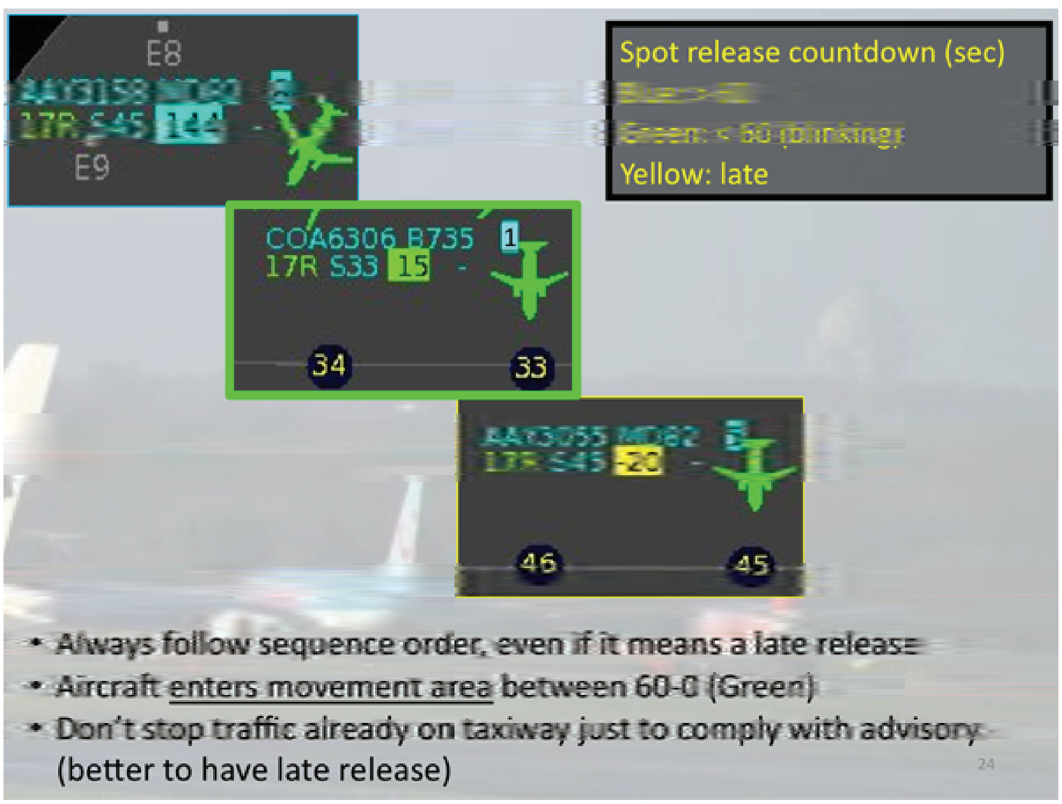

Advisory Conditions
Advisory Present
No Advisory
Datatag: Follow advisory
Timeline: Follow advisory
Current Operations
Modified Operations
20

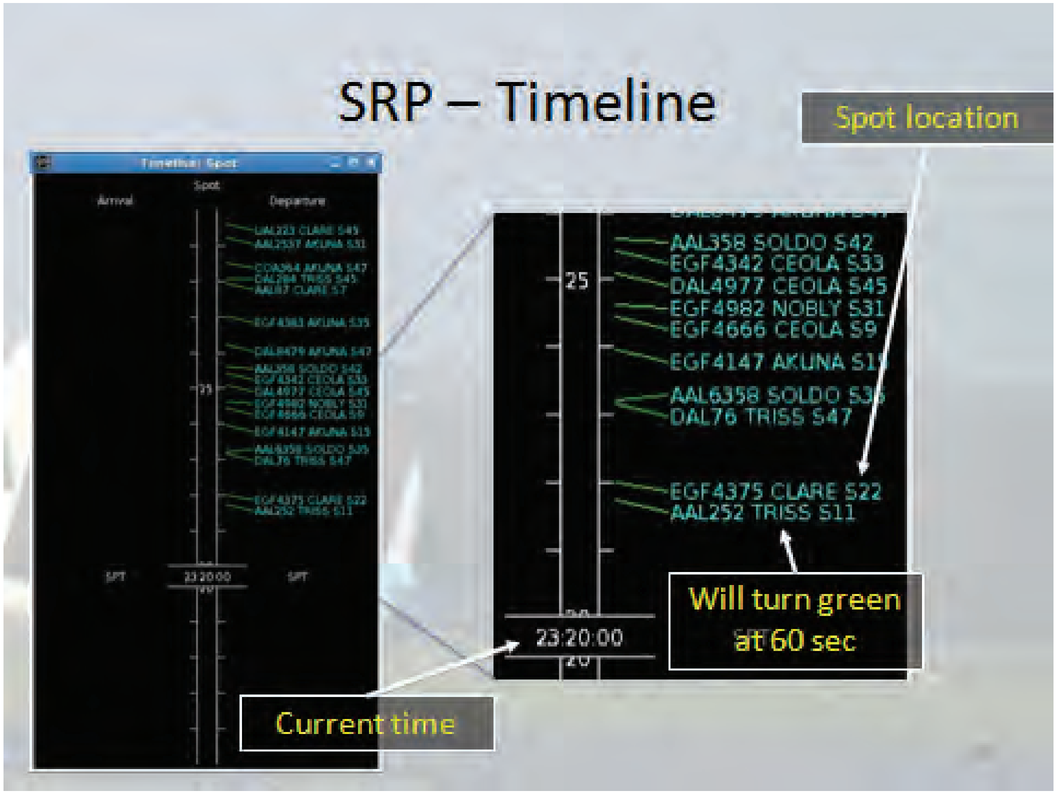
GROUND CONTROL ADVISORY: Spot Release Planner (SRP)

Spot Release Planner (SRP)

- Goal
  - Provide optimum spot release schedule that reduces taxi delay while maintaining maximum runway throughput
- Inputs
  - Flight information
  - Estimated taxi times and spot arrivals
  - Surface traffic conditions (taxiways/queues)
  - Prioritization schemes


SRP – Datatag
AAY83 1
18L S9 10
Spot release sequence number
Spot release countdown (sec)


E8
E9
COA6306 B735 1
17R S33 15
34
33
46
45
Spot release countdown (sec)
Yellow: late
• Always follow sequence order, even if it means a late release
• Aircraft enters movement area between 60-0 (Green)
• Don't stop traffic already on taxiway just to comply with advisory (better to have late release)
24

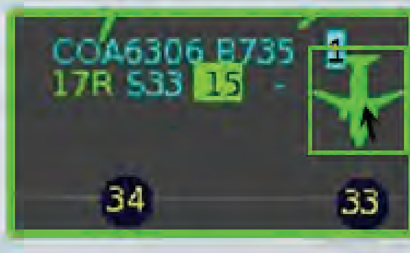


Recalculations – SRP

- SRP advisory will recalculate every 40 seconds
- Recalculation timer in upper left corner of display
- Expect change to your sequence number and countdown numbers, but not for top few
- Sometimes, there won't be a "1" in sequence because you already handled that aircraft, but update hasn't happened yet
- We don't expect this to happen, but if advisory changes status of aircraft mid-transmission, continue your planned clearance for that aircraft

Issue Spot Release Clearance

1. When aircraft sequence is 1, and you anticipate hitting 60-0 window, mouse click on aircraft icon (verify box around aircraft icon)



2. Verbally give taxi instruction

3. Hit appropriate hotkey on the keyboard to assign the taxi route as you give taxi instruction

Inner | Outer | Full Length | Bridge

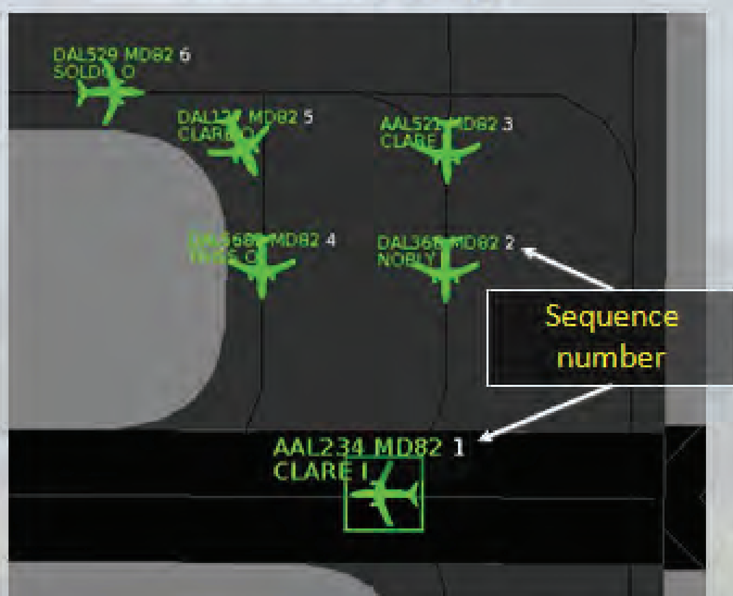
4. Receive readback from aircraft

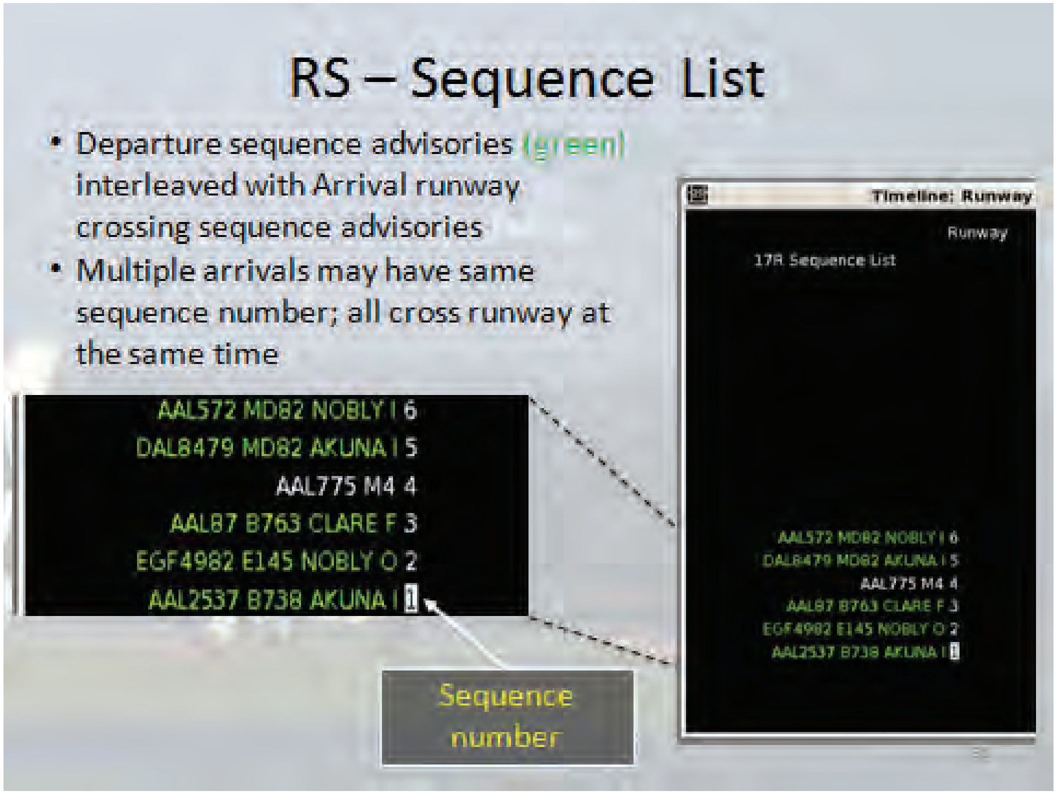
LOCAL CONTROL ADVISORY: Runway Scheduler (RS)

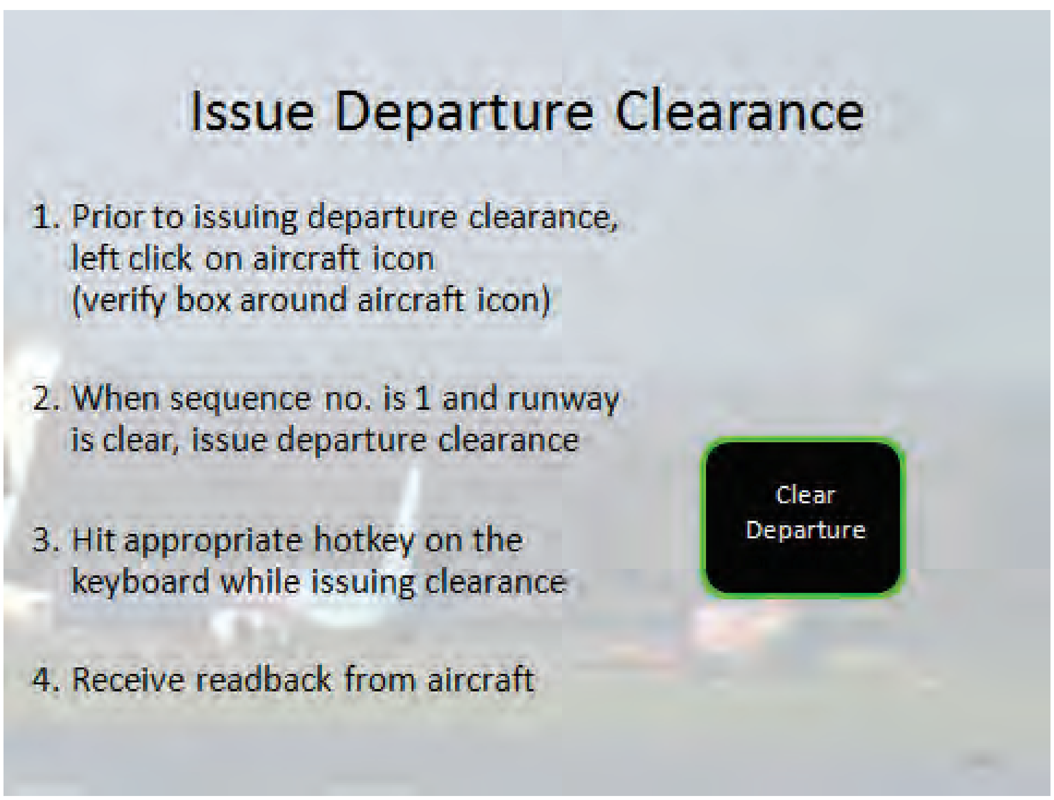
Runway Scheduler (RS)

- Goal
  - Provide optimal takeoff and crossing schedule for maximum runway usage while addressing operational constraints
- Inputs
  - Flight information
  - Estimated queue entry times
  - Availability to cross active runway
  - Prioritization schemes

RS – Datatag

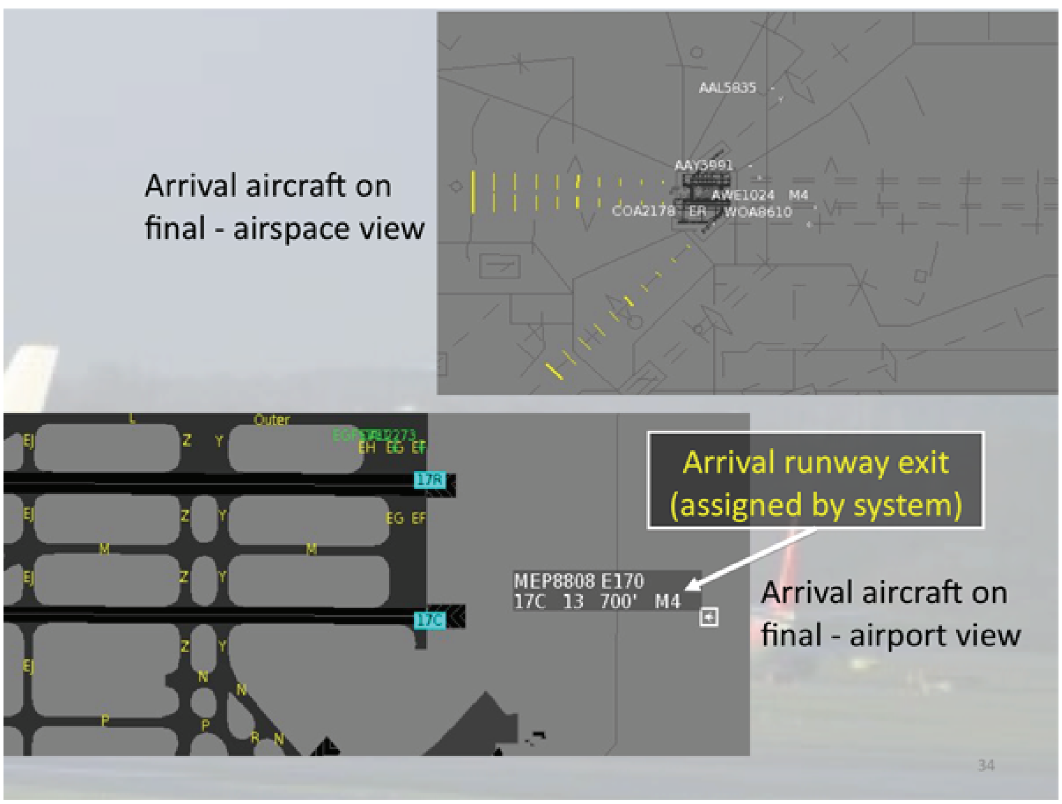



RS – Sequence List
• Departure sequence advisories (green) interleaved with Arrival runway crossing sequence advisories
• Multiple arrivals may have same sequence number; all cross runway at the same time
AAL572 MD82 NOBLY I 6
DAL8479 MD82 AKUNA I 5
AAL775 M4 4
AAL87 B763 CLARE F 3
EGF4982 E145 NOBLY O 2
AAL2537 B738 AKUNA I 1
Sequence number
Timeline: Runway
Runway
17R Sequence List

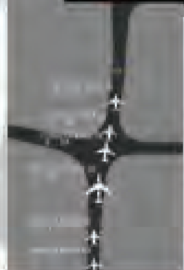

Issue Departure Clearance
1. Prior to issuing departure clearance, left click on aircraft icon (verify box around aircraft icon)
2. When sequence no. is 1 and runway is clear, issue departure clearance
3. Hit appropriate hotkey on the keyboard while issuing clearance
4. Receive readback from aircraft
Clear Departure

Recalculations – Runway Scheduler

- Runway Scheduler will recalculate every 40 seconds
- Recalculation timer in upper left corner of display
- Expect change to your sequence numbers, but not for top few
- Sometimes, there won't be a "1" in sequence because you already handled that aircraft, but update hasn't happened yet.
- We don't expect this to happen, but if advisory changes status of aircraft mid-transmission, continue your planned clearance for that aircraft



Change Arrival Runway Exit Assignment



1. If changing/assigning arrival runway exit, click on aircraft icon (verify box around aircraft icon)
2. Issue runway exit assignment
3. Hit appropriate key on the keyboard for assigned runway exit during transmission

M3 M4 M6 M7

1. Receive readback from aircraft

What to Expect During Hands-on Training (Thurs–Fri)

- Very light traffic at first
  - Plenty of time to get comfortable with displays for both positions
- Displays are (somewhat) configurable
  - Can change zoom/position on maps
  - Can move datatags manually (no automatic deconflict)
- Trainers will be on hand to explain procedures and answer any questions
- You will be exposed to all display configurations on both positions
- You will have an opportunity to calibrate separation benchmarks for departures

What to Expect During Data Collection (Starting Monday)

- Each run approximately 45 minutes
- Six runs per day
- You will switch positions between runs
- Advisory condition for each run will be reviewed immediately before the run begins
- After each run, you will complete a few short questionnaires to assess your situation awareness and workload
- At the end of each week, you will participate in an experimenter-led Q&A briefing

Post-Run Questionnaires

- Situation Awareness (objective)
  - Specific questions about what was happening and what you were planning to do next at the time the simulation ended
- Situation Awareness and Workload Ratings (subjective)
  - How well could you predict what event was about to occur next during this simulation?
  - How much mental activity was required during the last simulation?

End-of-Week Briefing

- Overall impressions about advisories and taxi-metering concept
- How might advisories/concept be improved
- How might advisories/concept be incorporated in decision support tools
- Additional functionality to support ground/local controller decisions, increase efficiency, alleviate workload, etc.
- As you have thoughts/ideas about these topics during the week, keep notes, and we'll discuss at end-of-week briefing

Things to Remember

- A sequence number of "1" means "<u>next</u>", not "<u>go</u>"
- Please don't improvise taxiway and runway usage
  - For example, no 17C departures
  - This will interfere with our data collection
- Please try to follow instructions/advisories for each run!
  - You may not agree with the advisory
  - You may be able to "out-perform" the advisory

  BUT

  - If you don't follow the advisory, we won't collect the data we need to refine and improve the algorithms!


QUESTIONS?
41

APPENDIX D: PSEUDO-PILOT TRAINING MATERIAL

This section contains the two training materials given to the pseudo-pilots during the April–May 2010 data collection runs.

1. Spot and Runway Departure (SARDA) Shakedown Simulation
2. Pseudo-Pilot Roles and Responsibilities Description

Spot and Runway Departure (SARDA) Shakedown Simulation

This document presents the SARDA goals, airport layout, overview of the pilot station, and the roles and responsibilities of each pseudo-pilot.[1]

[1] Slides created on PowerPoint file *PseudoPilotTraining_Apr10.pptx*.

SPOT AND RUNWAY DEPARTURE ADVISORY (SARDA) SHAKEDOWN SIMULATION

Pseudo-Pilot Training

Apr 22, 2010

1

Outline

- User Objectives
- SARDA Goals
- Airport Layout
- Pilot Station Overview
- Pilot Roles and Responsibilities

2

User Objectives

- Maintain radio communication with controllers
- Move aircraft as directed by controller
  - Departures: from spot to runway 17R for takeoff
  - Departures: onto Bridge route to runway 18L
  - Arrivals: from runway to gate
- Hand off flights to next pilot as they approach the other pilot's sector boundary
- Receive flights from another pilot when they cross into your pilot sector
- Manage arrivals received from another pilot, moving into appropriate spots
- Do not control aircraft in ramp area (automatic pilot)

3

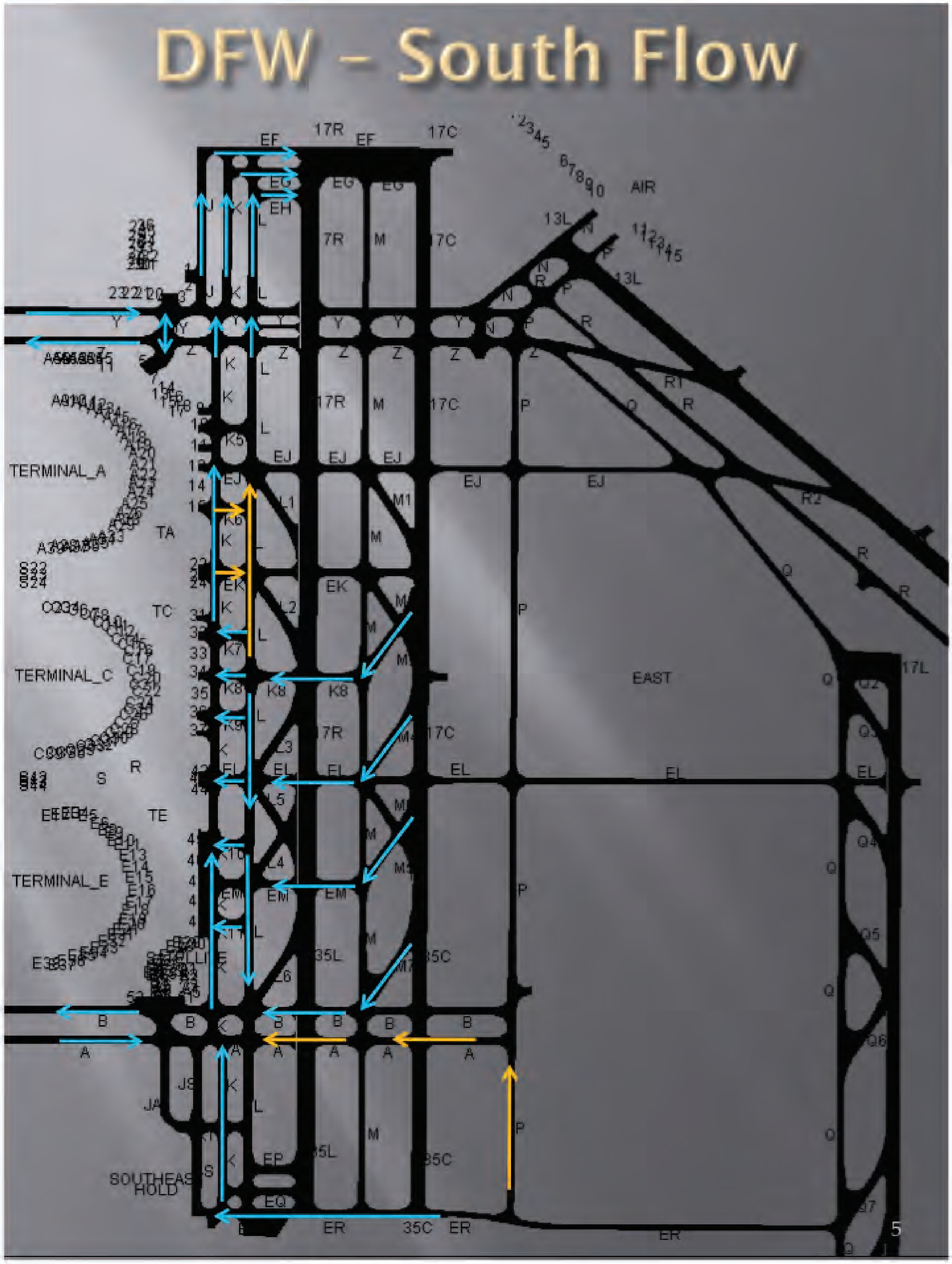
SARDA Goals

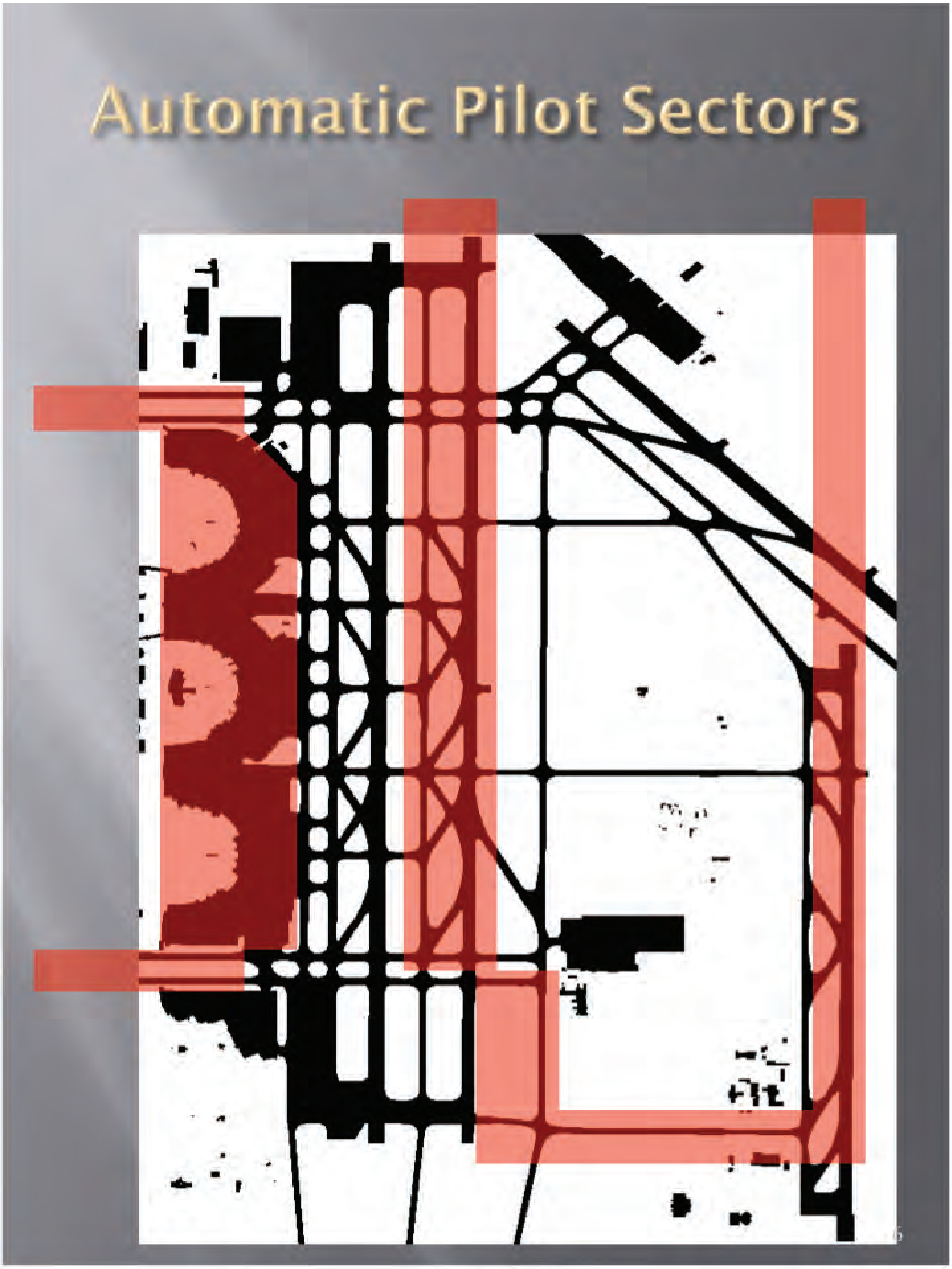
Motivation

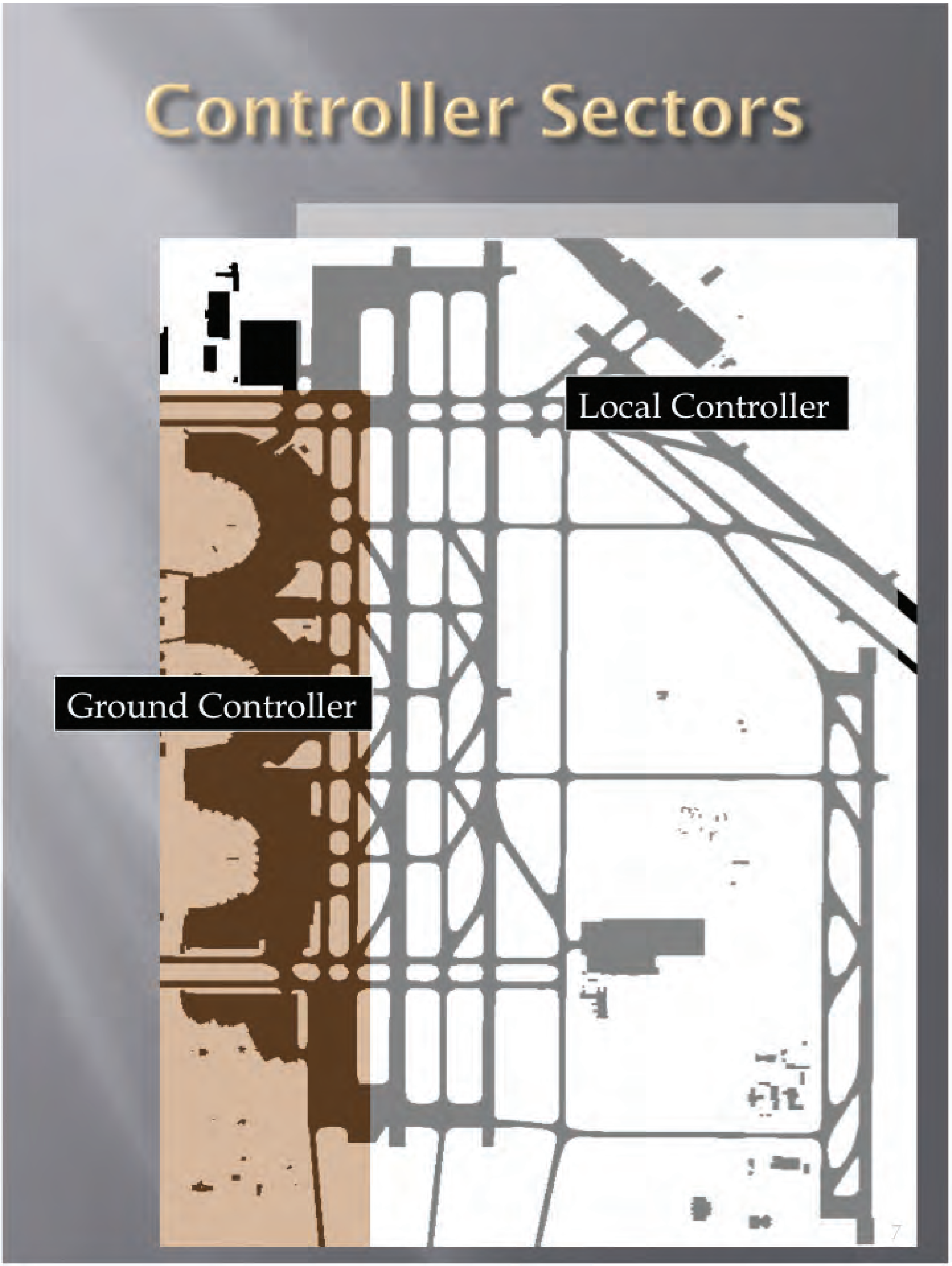
- Currently, departure delay held at runway
- Alleviate departure queue & taxiway congestion for efficiency
- Environmental impact: stop & go / slow taxi operations lead to inefficient fuel consumption and higher emissions

Operational Concept/Goals

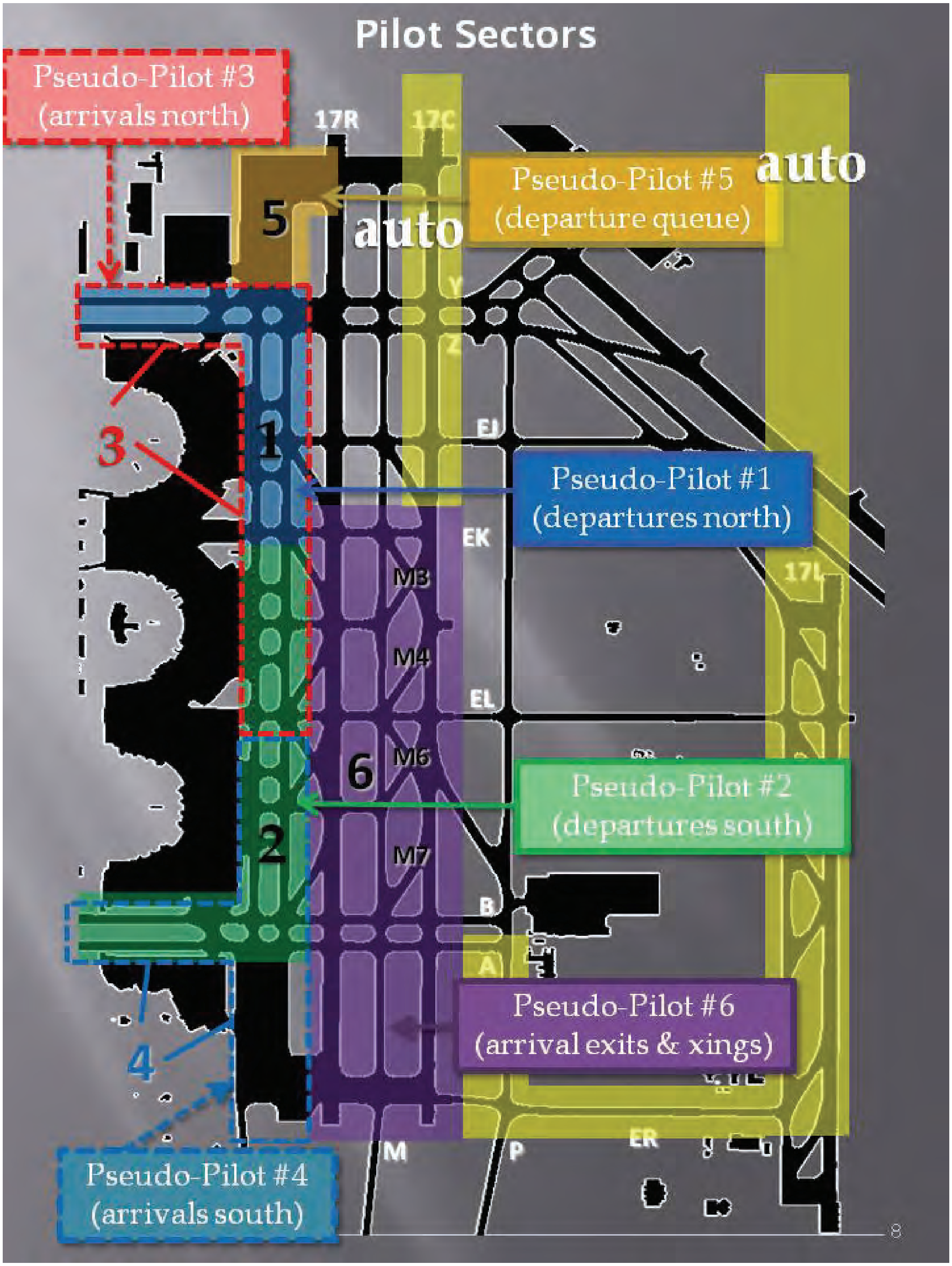
- Meter departure aircraft from the spot instead of oversaturating the departure queue
- Maximize efficiency of surface operations
- Reduce taxi delay to reduce fuel, emissions
- No concession in runway throughput


DFW – South Flow
TERMINAL_A
TERMINAL_C
TERMINAL_E
EAST
17R
17C
17L
35L
35C
13L
AIR
SOUTHEAST HOLD
5


Automatic Pilot Sectors

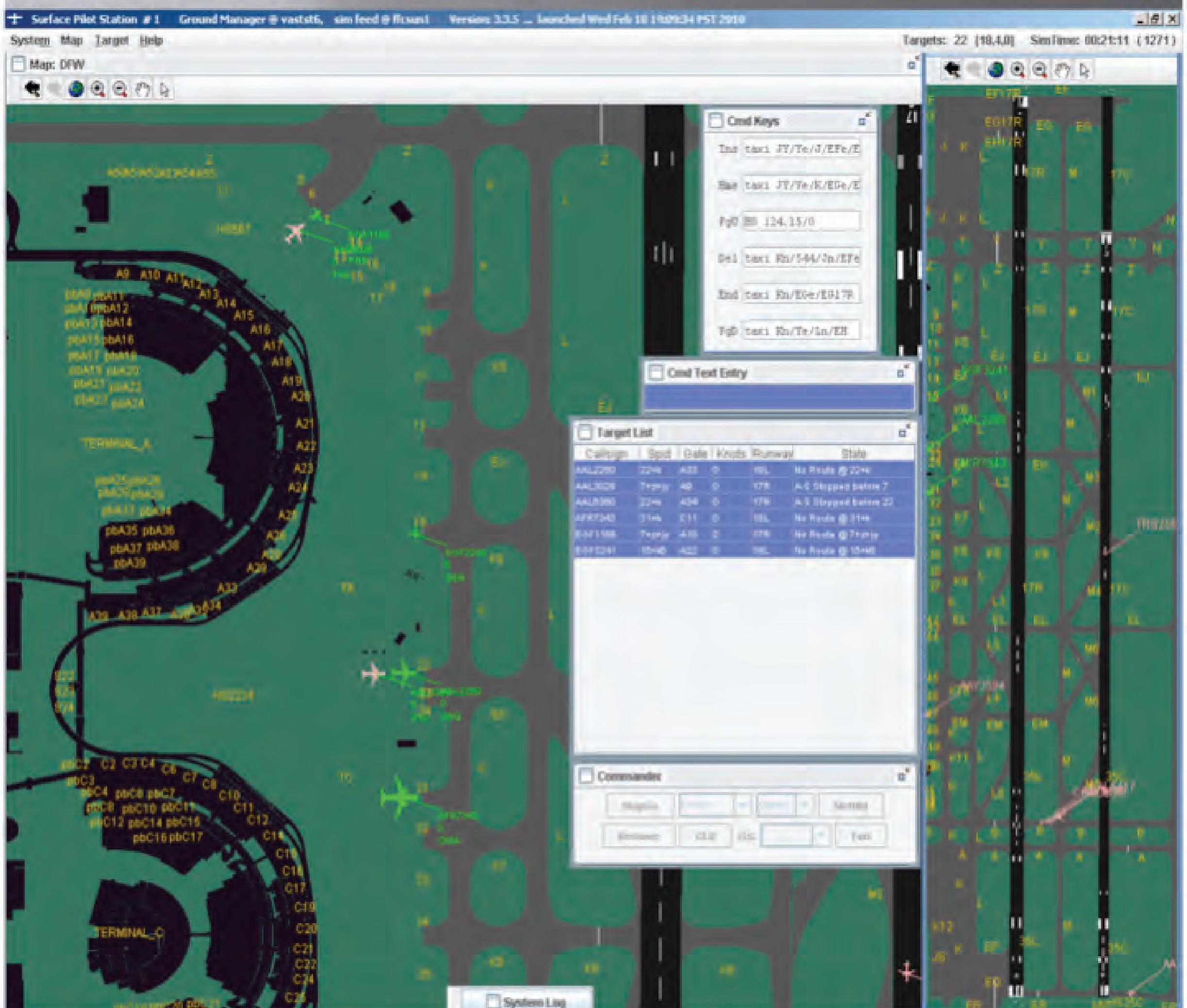


Controller Sectors
Local Controller
Ground Controller
7



Pilot Sectors
Pseudo-Pilot #3
(arrivals north)
17R
17C
Pseudo-Pilot #5
(departure queue)
auto
5
auto
Y
Z
3
1
EJ
Pseudo-Pilot #1
(departures north)
EK
M3
17L
M4
EL
M6
6
Pseudo-Pilot #2
(departures south)
2
M7
B
A
Pseudo-Pilot #6
(arrival exits & xings)
4
M
P
ER
Pseudo-Pilot #4
(arrivals south)
8

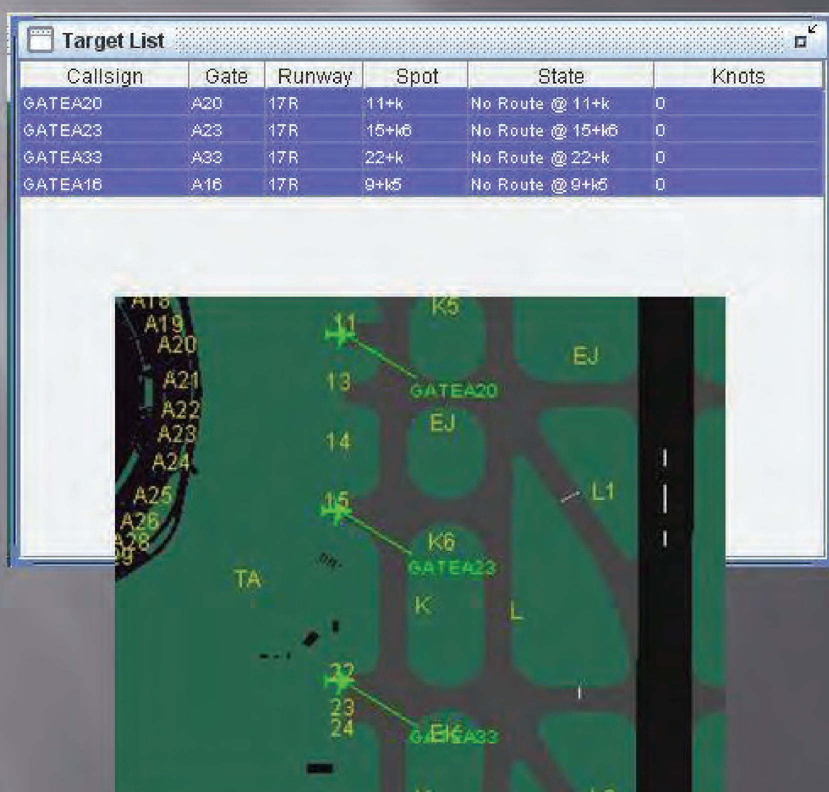
Pilot Station



9

Aircraft Ownership

An aircraft is "owned" by the pseudo-pilot when it shows up in the target list and its datatag is green on the map display



10

Pilot Display Colors

Green datatag
- You own

Orange
- You are actively controlling

Pink
- Someone else owns or anti-stacking is active

Magenta
- Automatic pilot spool-up in ramp

Yellow flashing
- Handoff initiated

11

Roles & Responsibilities

Everyone

- Ensure safety and separation between aircraft on taxiways
- Do not control aircraft in ramp area (automatic pilot)
- Left click to select aircraft on map or target list
- Left click on nodes to draw route
- Right click after route is drawn to indicate "go"
- Ignore "noAirport" in some datatags
- Notify pilot room monitor about errant aircraft
- Keep excess radio chatter down due to audio recording

Initial Surface Aircraft

- Use "F2" to grab ownership of aircraft of flights in your area, if needed
- Move aircraft forward a little, then click "Stop" in Commander window

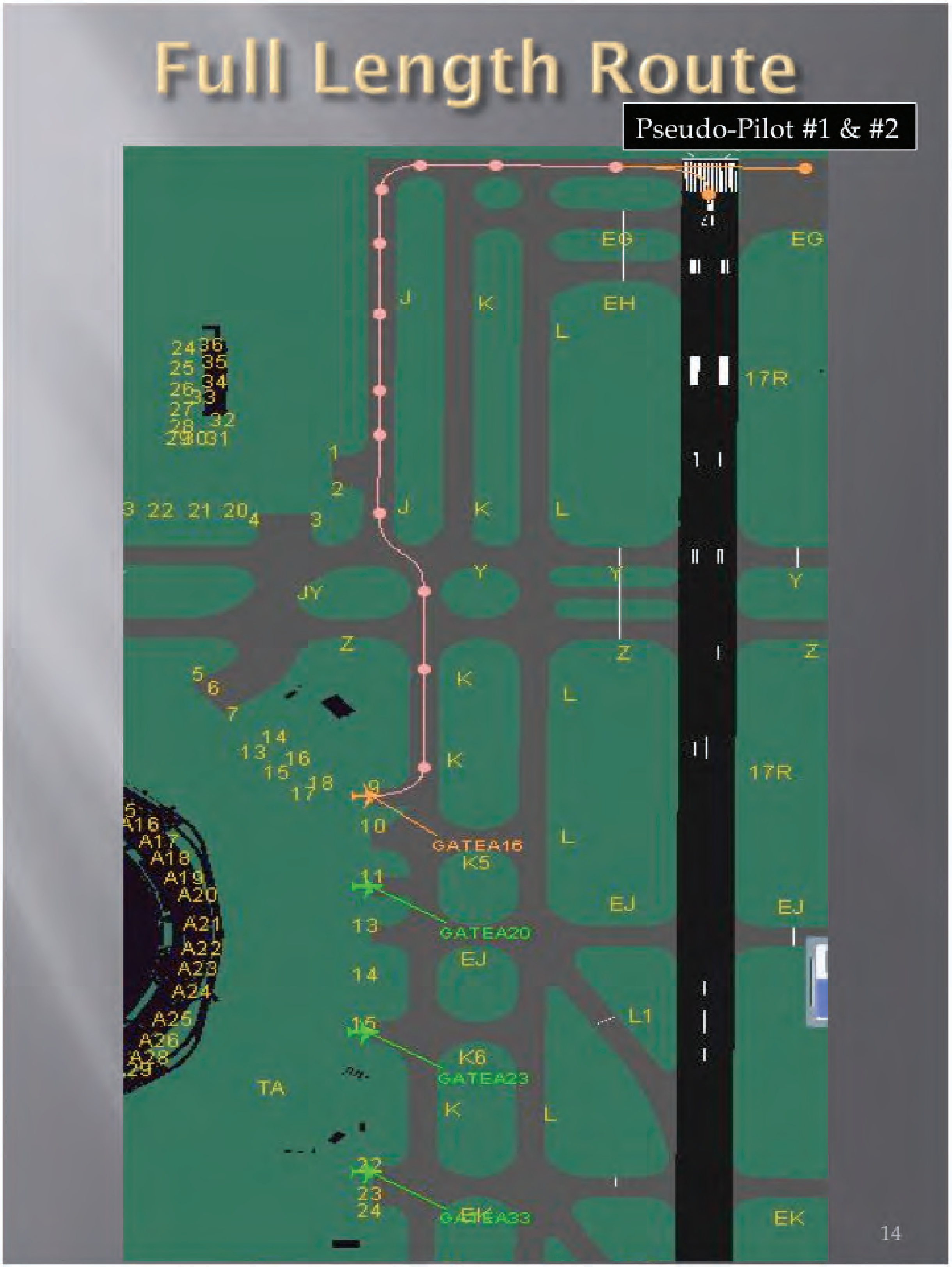
12

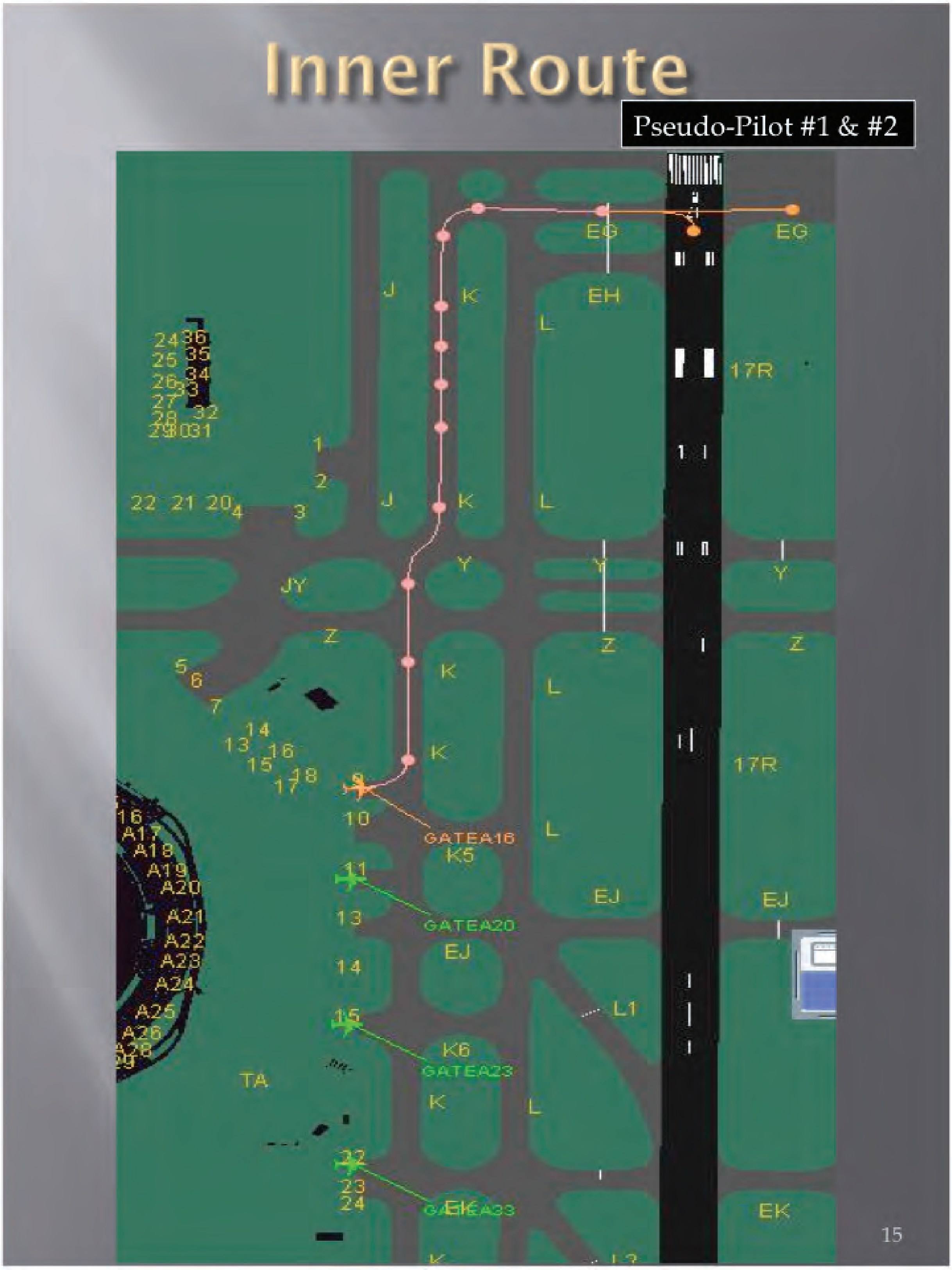
Roles & Responsibilities

Pilots 1, 2

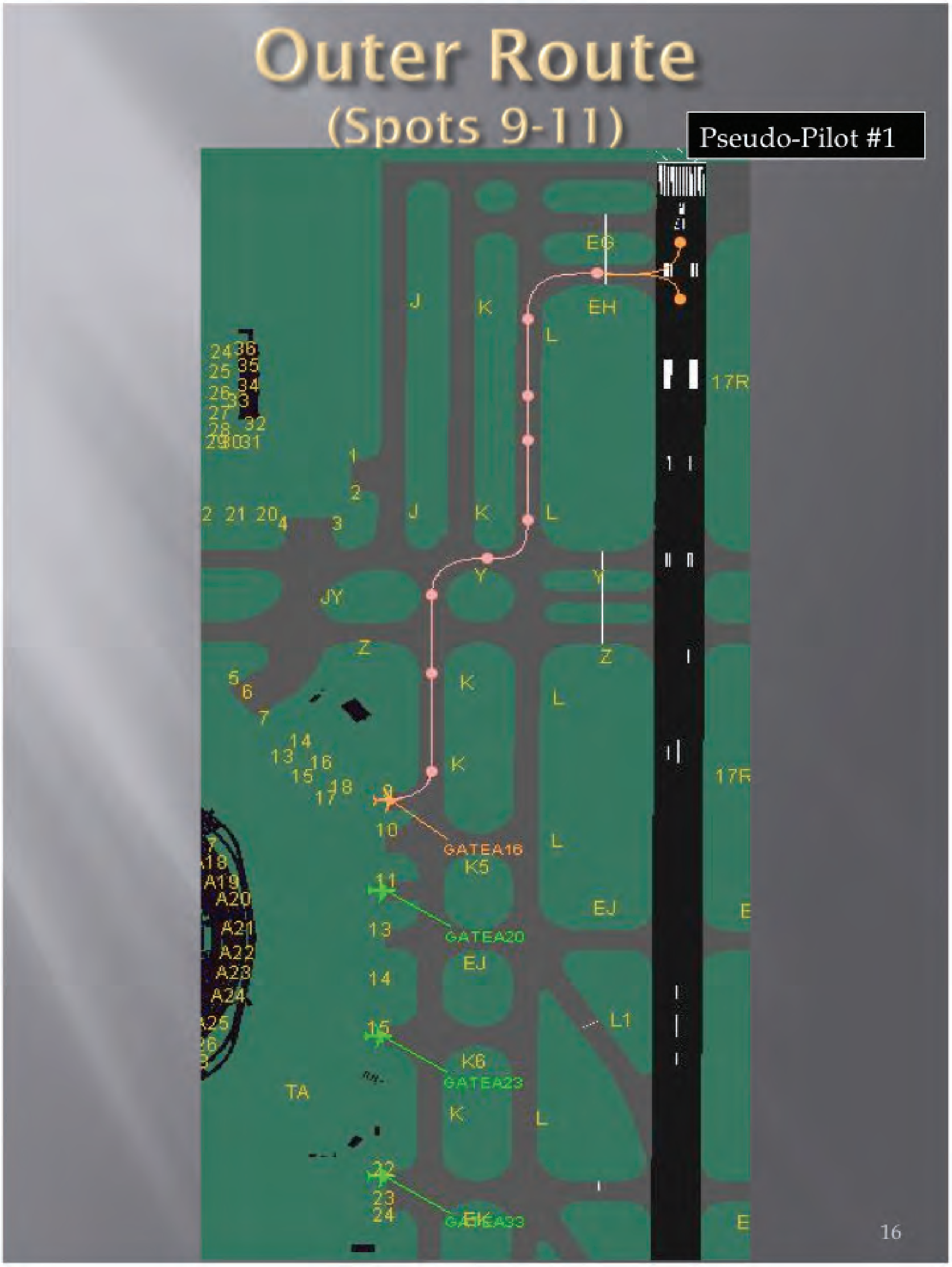
- Monitors frequency: *ground 121.65* and controls *departure* aircraft from spot to departure runway
- Release aircraft from the spot at the time instructed by the ground controller
- Move aircraft from the spot to designated runway as directed by the ground controller. This will either be the Full length (J->EF), Inner (K->EG), Outer (L->EH), or Bridge route (Z->18L).
- NEW: Outer route will take L northbound starting from EK
- Increase speed of aircraft to 15 knots after leaving the spot
- Hand off to next pilot at specified location

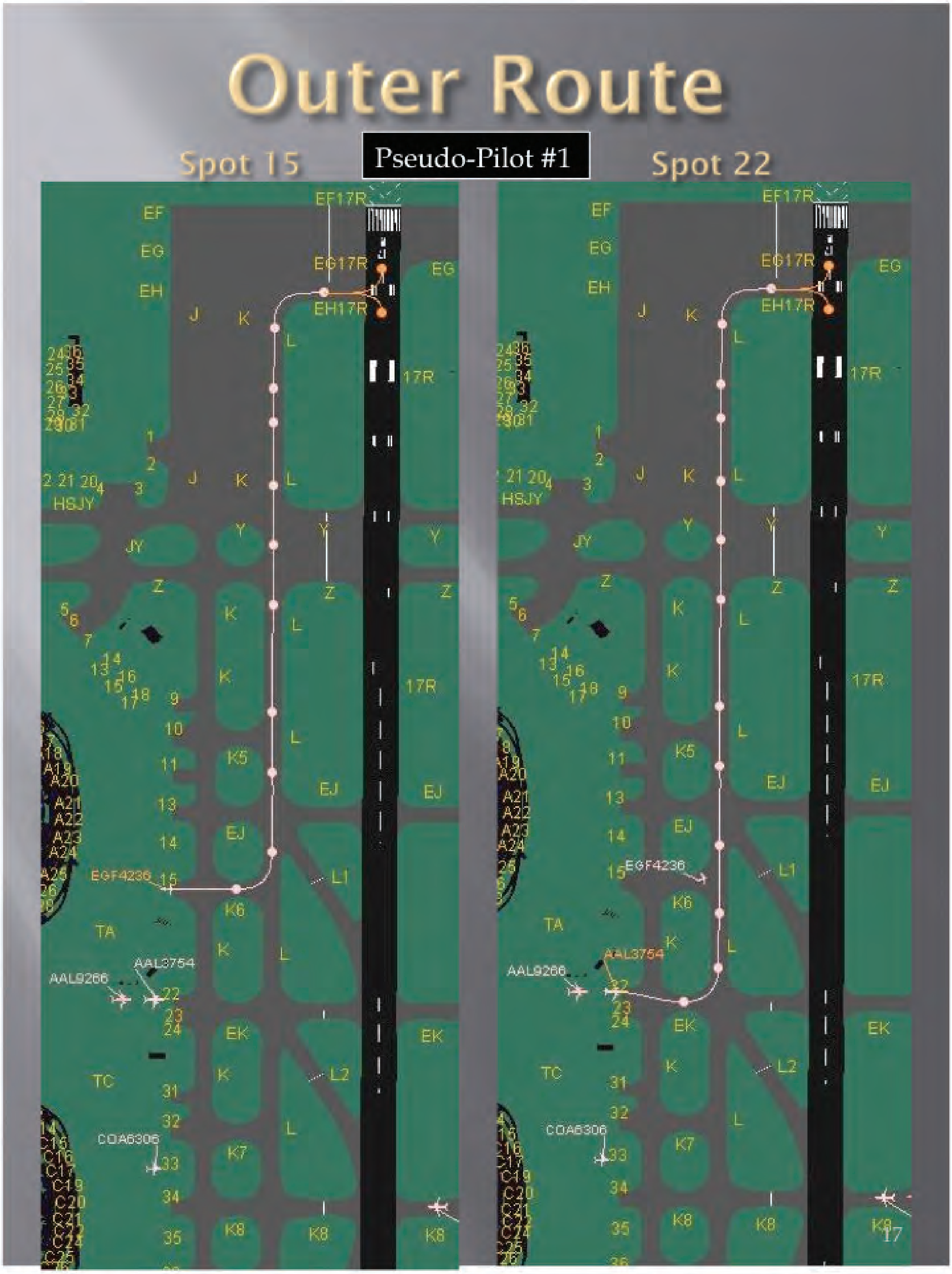
13

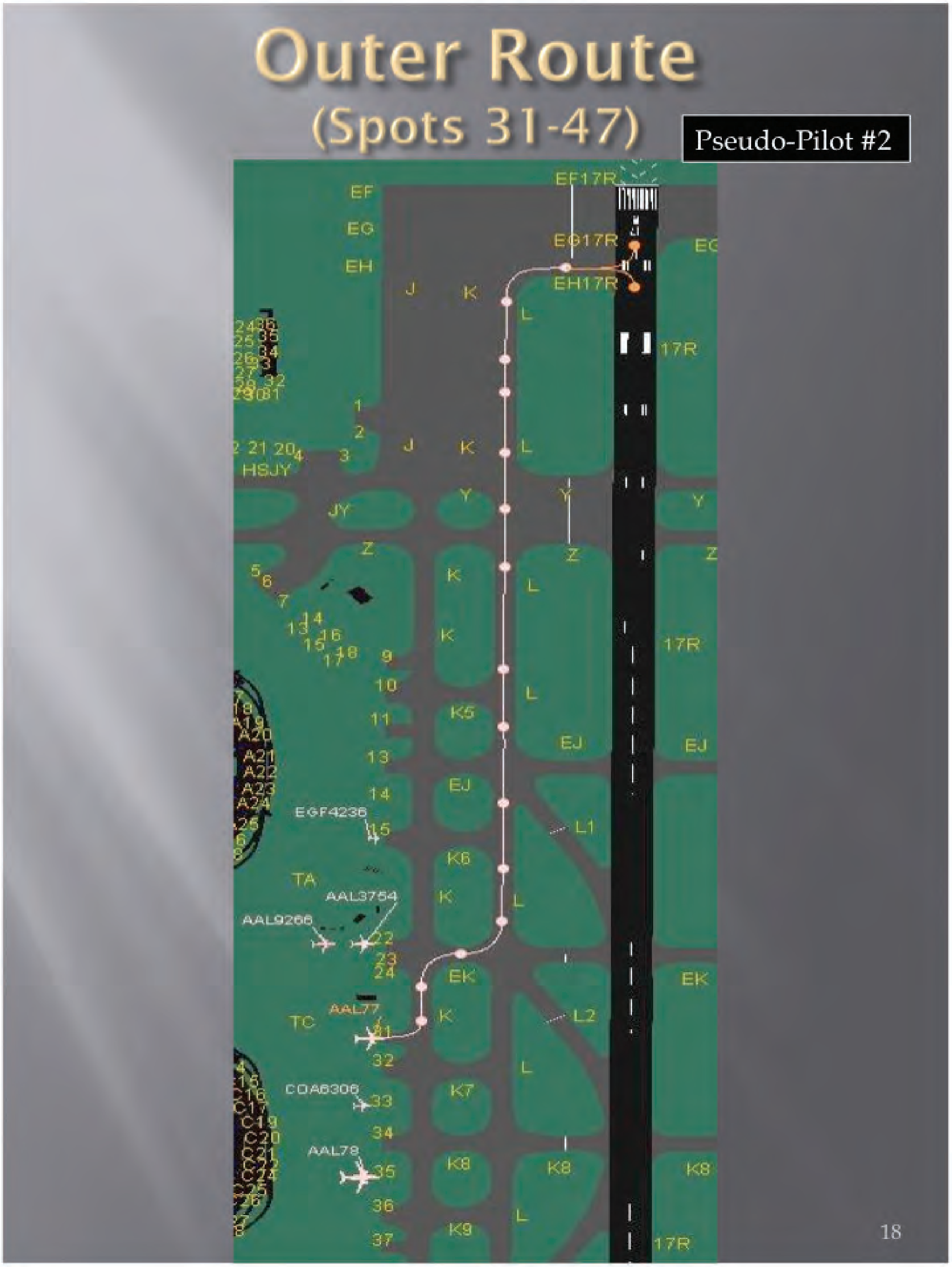

Full Length Route
Pseudo-Pilot #1 & #2
J
K
L
EG
EH
17R
Y
JY
Z
GATEA16
GATEA20
GATEA23
K5
K6
EJ
L1
TA
EK
14



Inner Route
Pseudo-Pilot #1 & #2
EG
EG
J
K
EH
L
17R
J
K
L
Y
Y
Y
JY
Z
Z
Z
K
L
K
17R
L
GATEA16
K5
EJ
EJ
GATEA20
EJ
L1
K6
GATEA23
TA
K
L
EK
EK
15

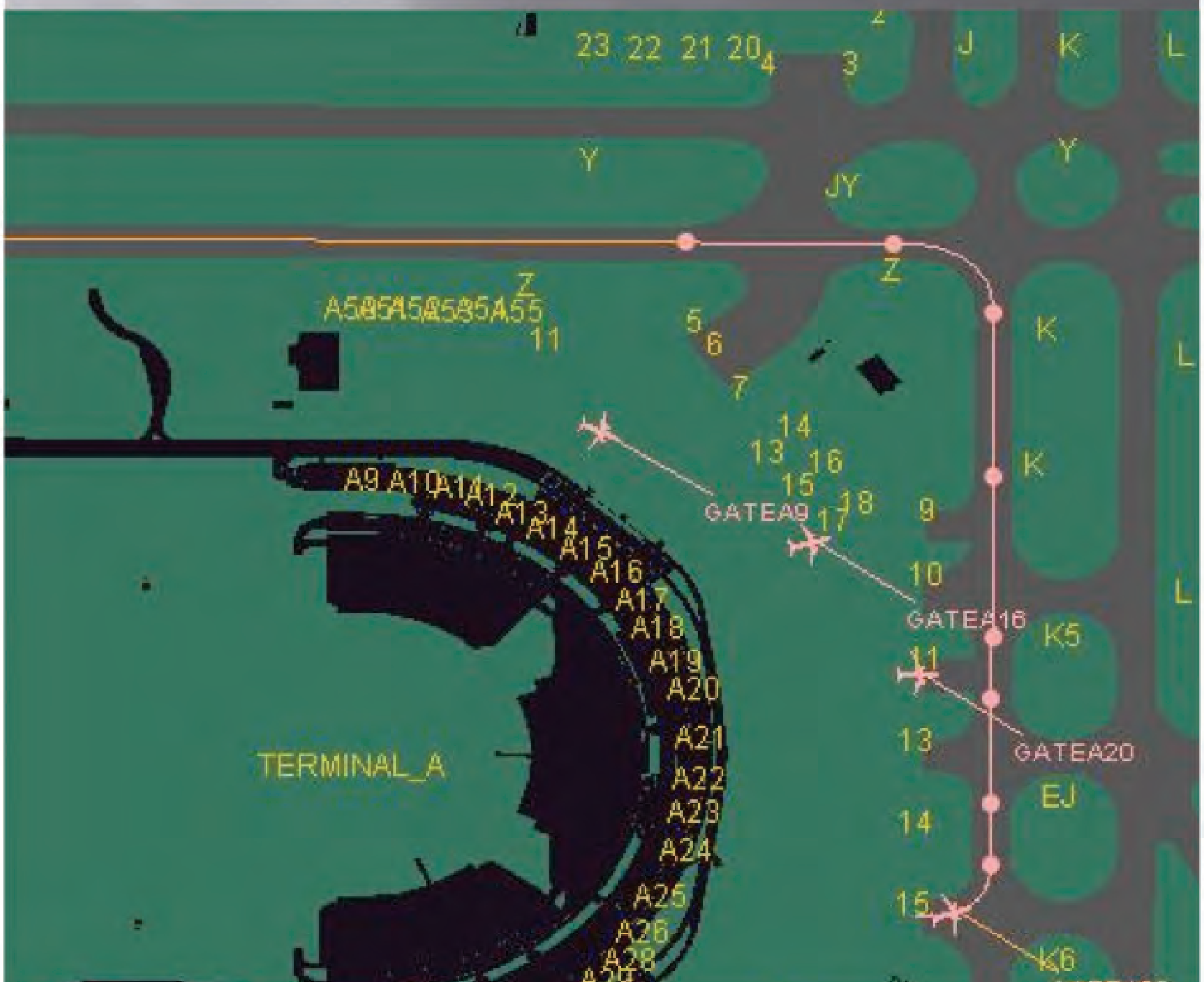

Outer Route
(Spots 9-11)
Pseudo-Pilot #1
EG
EH
J
K
L
17R
Y
JY
Z
GATEA16
K5
GATEA20
EJ
L1
K6
GATEA23
TA
GATEA33
16


Outer Route
Spot 15
Pseudo-Pilot #1
Spot 22
EF17R
EG17R
EH17R
17R
EGF4236
AAL3754
AAL9266
COA6306
17


Outer Route
(Spots 31-47)
Pseudo-Pilot #2
EF17R
EG17R
EH17R
17R
EF
EG
EH
J
K
L
Y
JY
Z
K5
K6
K7
K8
K9
EJ
EK
L1
L2
TA
TC
HSJY
EGF4236
AAL3754
AAL9266
AAL77
CDA6306
AAL79
31
32
33
34
35
36
37
18

18L Departure Route ("Bridge")

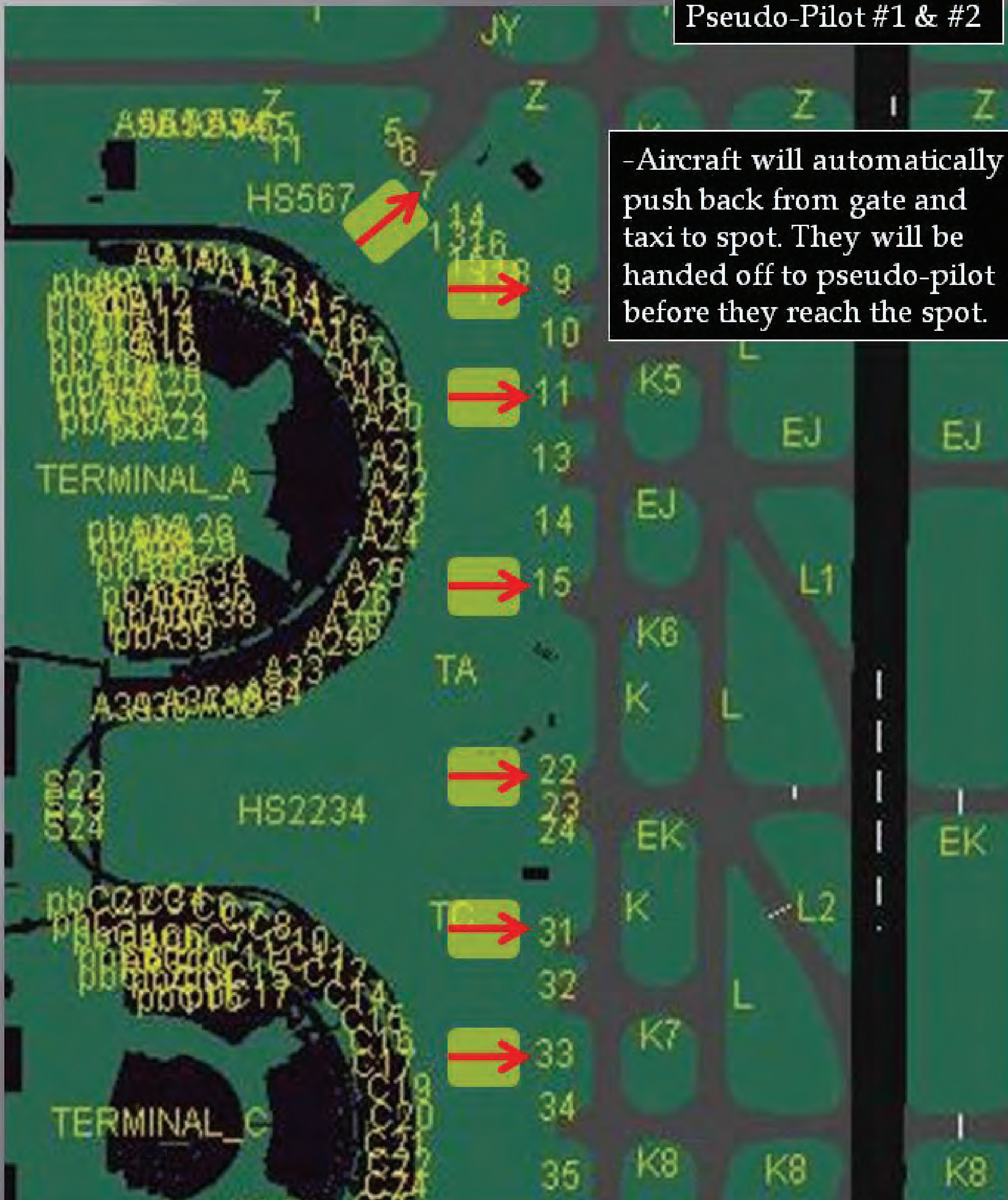
Pseudo-Pilot #1 & #2



19

Handoff Points and Procedures

Pseudo-Pilot #1 & #2



-Aircraft will automatically push back from gate and taxi to spot. They will be handed off to pseudo-pilot before they reach the spot.

20

Roles & Responsibilities

Pilots 3, 4

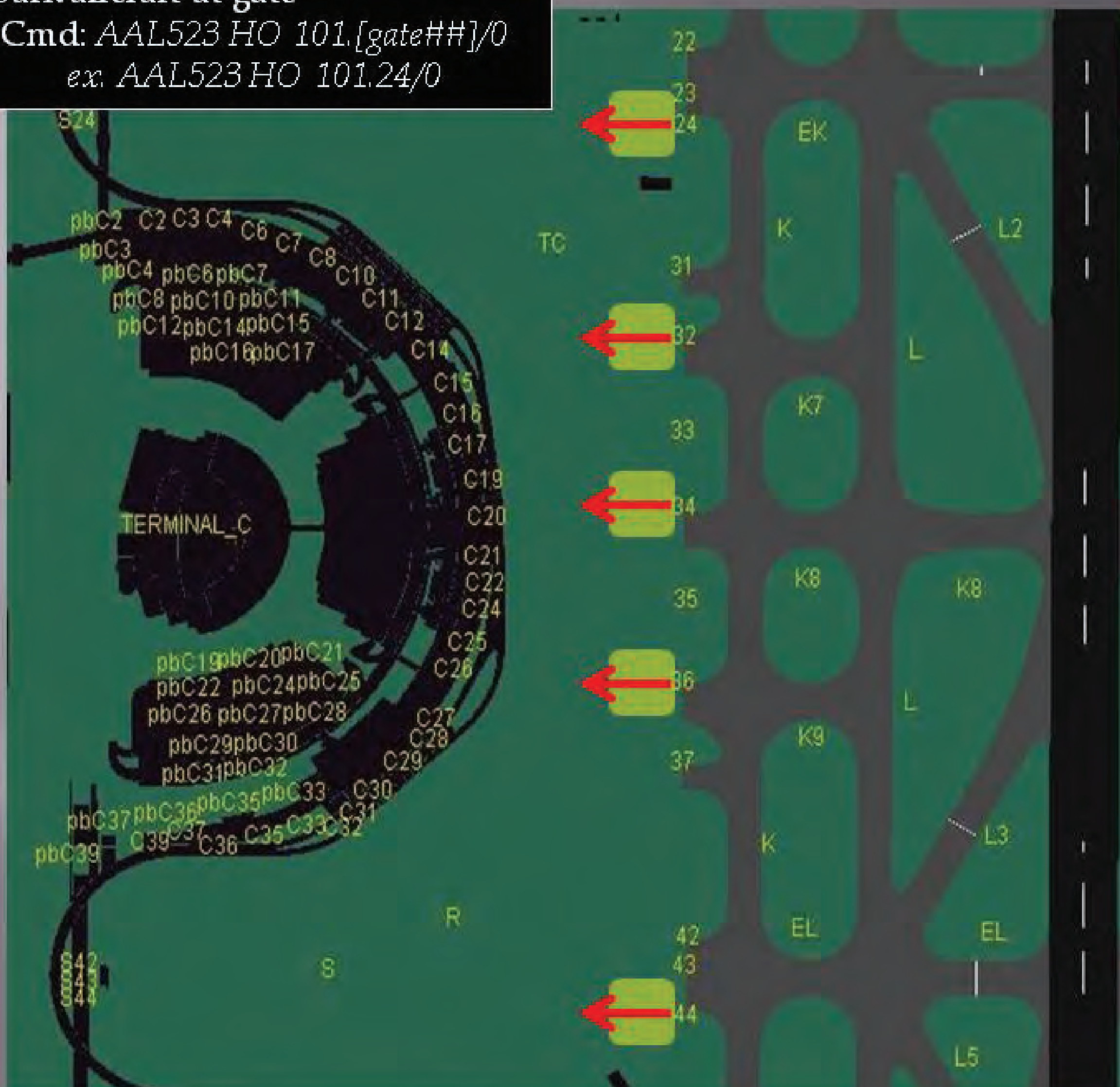
- Monitors frequency: *ground 121.65* and controls *arrival* aircraft taxiing from runway to spot
- Move aircraft along taxiway to spots as directed by ground controller
- Hand off to automatic pilot at spots or to next pilot at specified location
- NEW: Arrivals from 17L to Terminal A and some gates in Terminal C (spots 5–37) are routed to taxiway A to cross 17C and 17R
- Handoff to automatic gate pilot nomenclature: 10X.ZZ/0
  - X = 0 for Terminal A (100)
  - X = 1 for Terminal C (101)
  - X = 2 for Terminal E (102)
  - ZZ = gate number with 2 digits
  - *HO 100.09/0* is Terminal A, gate 9
  - *HO 101.12/0* is Terminal C, gate 12
  - *HO 102.25/0* is Terminal E, gate 25

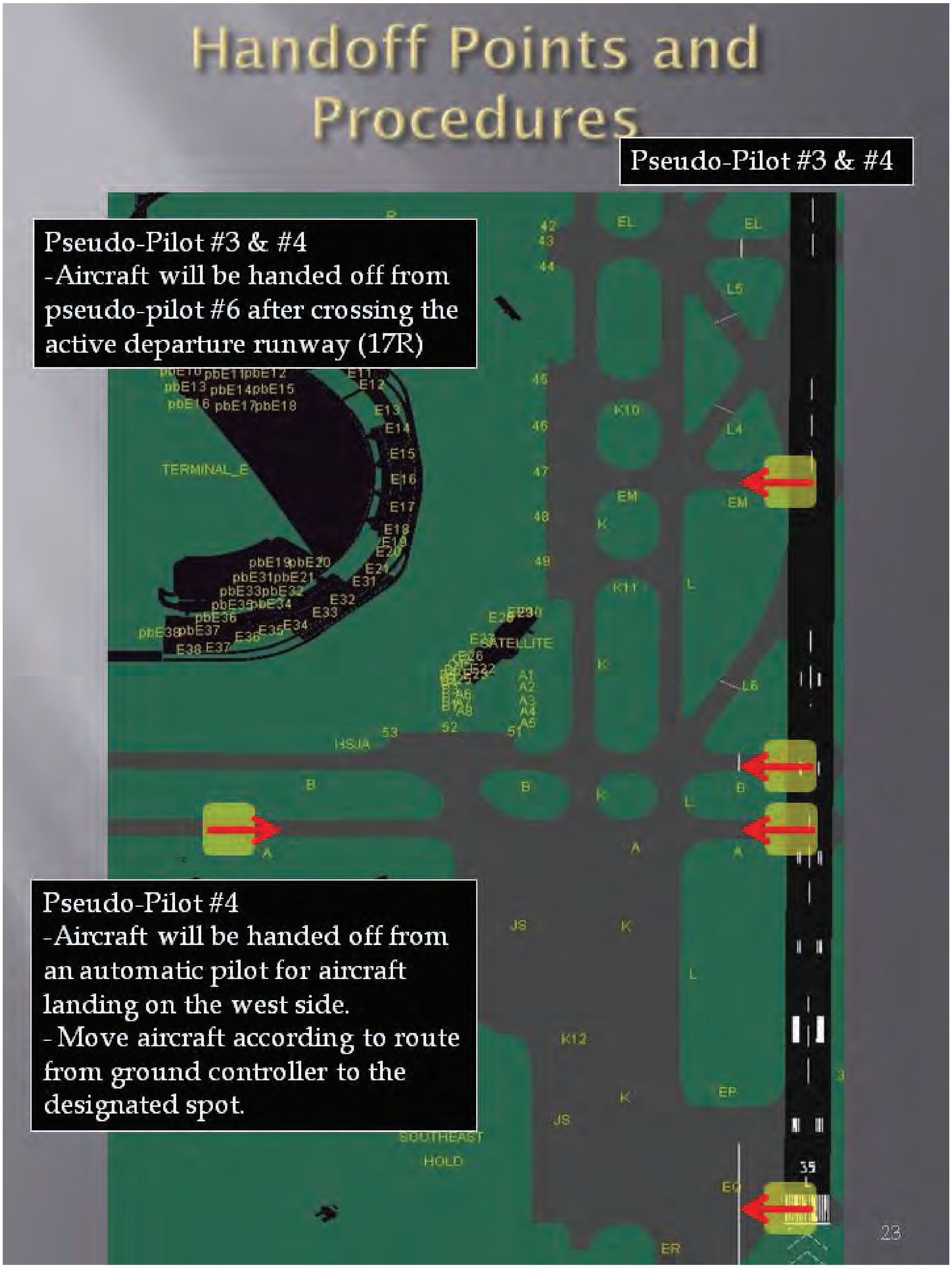
21

Handoff Points and Procedures

Pseudo-Pilot #3 & #4

-Hand off to automatic pilot to park aircraft at gate
-Cmd: *AAL523 HO 101.[gate##]/0*
ex. AAL523 HO 101.24/0




Handoff Points and Procedures
Pseudo-Pilot #3 & #4
Pseudo-Pilot #3 & #4
-Aircraft will be handed off from pseudo-pilot #6 after crossing the active departure runway (17R)
Pseudo-Pilot #4
-Aircraft will be handed off from an automatic pilot for aircraft landing on the west side.
- Move aircraft according to route from ground controller to the designated spot.
TERMINAL_E
SATELLITE
SOUTHEAST HOLD
23

Handoff Points and Procedures

Pseudo-Pilot #3

-Aircraft will be handed off from an automatic pilot for aircraft landing on the west side.
- Move aircraft according to route from ground controller to bring aircraft to the designated spot.

24

Roles & Responsibilities

Pilot 5

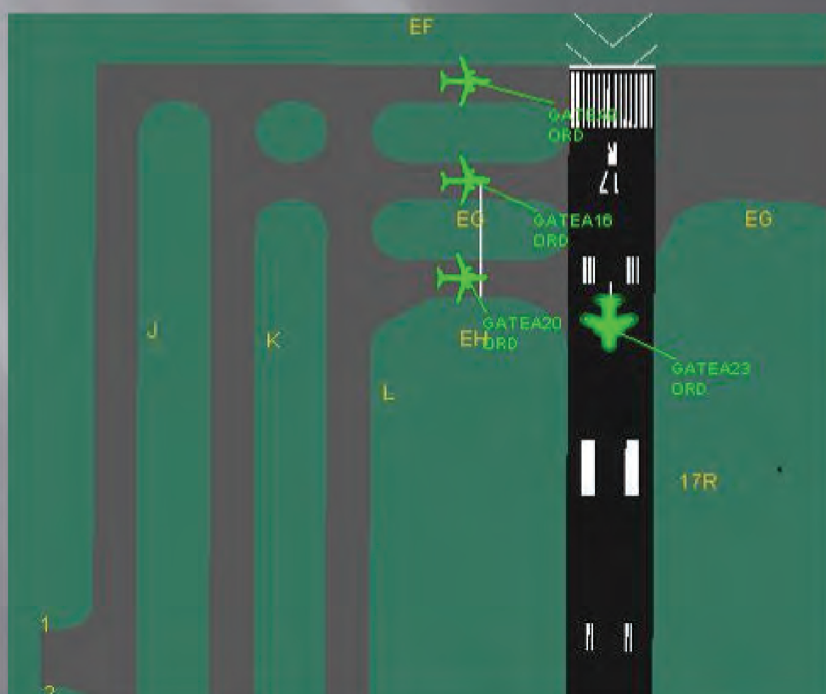
- Monitors frequency: *local 126.55* and controls aircraft departing from 17R
- Move aircraft onto runway and take off as directed by local controller

25


Handoff Points and Procedures
Pseudo-Pilot #5
-Depart aircraft using handoff procedure to automatic pilot
-Cmd: *AAL523 HO 127.5/0*
-Shortcut: *Del*
-Take aircraft from pseudo-pilot #1
-Cmd: *F2*
26

Departing Aircraft

Once an aircraft is released for departure, the icon will appear blurry when it begins its takeoff roll



27

Roles & Responsibilities

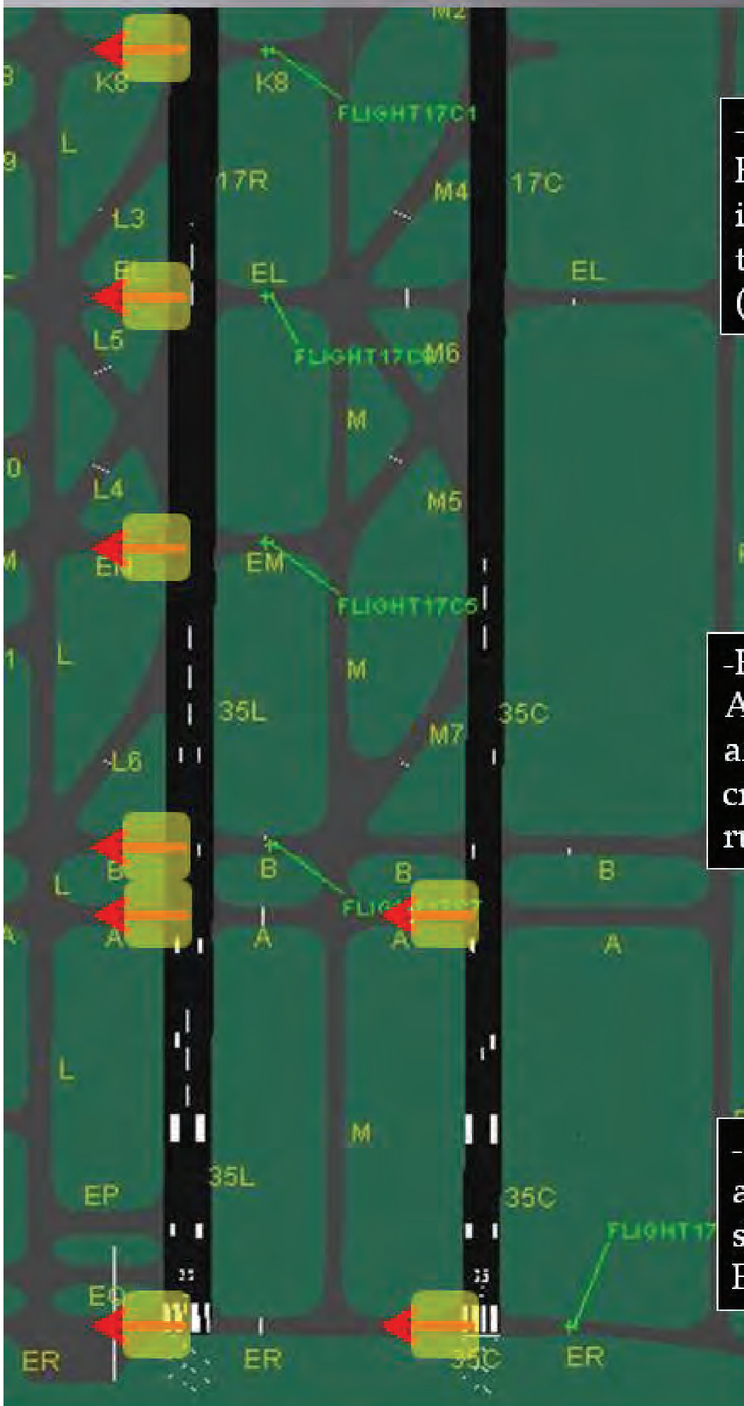
Pilot 6

- Monitors frequency: *local 126.55* and controls aircraft arriving on 17C
- Take the indicated high-speed exit off 17C if directed by local controller; default exit is already specified
- Move aircraft across runways 17R and 17C as directed by local controller
- Hand off to next pilot at specified location
- NEW: Arrivals from 17L to Terminal A and some gates in Terminal C (spots 5–37) are routed to taxiway A to cross 17C and 17R

28

Handoff Points and Procedures

Pseudo-Pilot #6



-Hand off aircraft on K8 or EL to pseudo-pilot #3 after issuing command to cross the active departure runway (17R)

-Hand off aircraft on EM, B, A, or ER to pseudo-pilot #4 after issuing command to cross the active departure runway (17R)

-Aircraft handed off by automatic pilot and will hold short of runway 17C on A or ER

29

Summary

- Maintain radio communication with controllers
- Move aircraft as directed by controller
  - Departures: from spot to runway 17R for takeoff
  - Departures: onto Bridge route to runway 18L
  - Arrivals: from runway to gate
- Hand off flights to next pilot as they approach the other pilot's sector boundary
- Receive flights from another pilot when they cross into your pilot sector
- Manage arrivals received from another pilot, moving into appropriate spots
- Do not control aircraft in ramp area (automatic pilot)

30

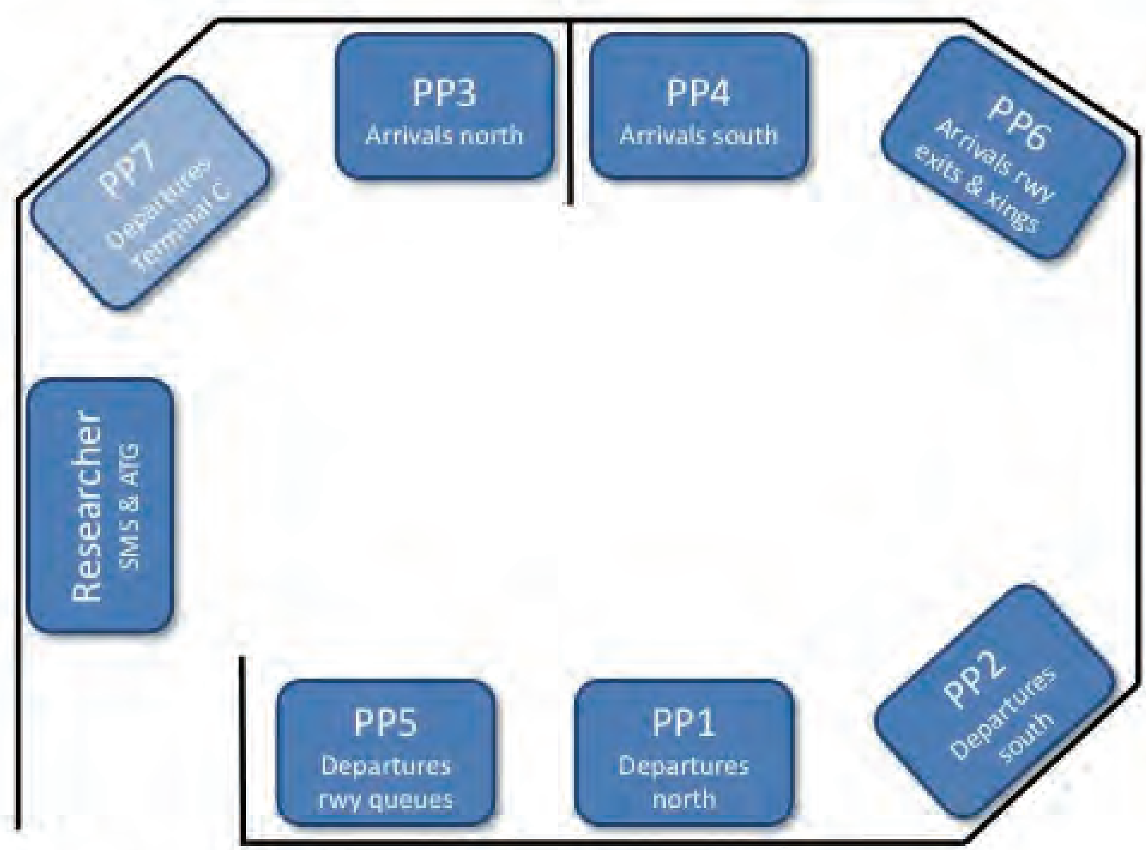
Pseudo-Pilot Roles and Responsibility Description

The training package presents a detailed description for working each pseudo-pilot station, such as specific aircraft control commands appropriate to that station.[2]

The document includes a description for an optional seventh pseudo-pilot, which was not exercised during the April–May 2010 data collection runs.

[2] Slides created on PowerPoint file *Pseudo_Pilot_Control_Sectors_v4.pptx*.

Pilot Room Layout



1

2

AAL	AMERICAN
AAY	ALLEGIANT
ACA	AIR CANADA
AFR	AIRFRANS
AMF	AMFLIGHT
AMW	AIR MIDWEST
AMX	AEROMEXICO
ASQ	ACEY
ATN	AIR TRANSPORT
AWE	CACTUS
BAW	SPEEDBIRD
BSK	BISCAYNE
BTA	JET LINK
CHQ	CHAUTAUQUA
COA	CONTINENTAL
COM	COMAIR
CPZ	COMPASS ROSE

DAL	DELTA
EGF	EAGLE FLIGHT
FFT	FRONTIER
FLG	FLAGSHIP
FRL	FREEDOM AIR
KAL	KOREAN AIR
MEP	MIDEX
MES	MESABA
MXA	MEXICANA
NWA	NORTHWEST
RPA	BRICKYARD
SCX	SUN COUNTRY
SKW	SKYWEST
TRS	CITRUS
UAL	UNITED
USA	CACTUS
WOA	WORLD

Pseudo-Pilot Display Colors

Green datatag :	You own
Orange :	You are actively controlling
Pink :	Someone else owns or anti-stacking is active
Magenta :	Automatic pilot spool-up in ramp
Yellow flashing :	Handoff initiated

Pseudo-Pilot Display Colors

Green datatag :	You own
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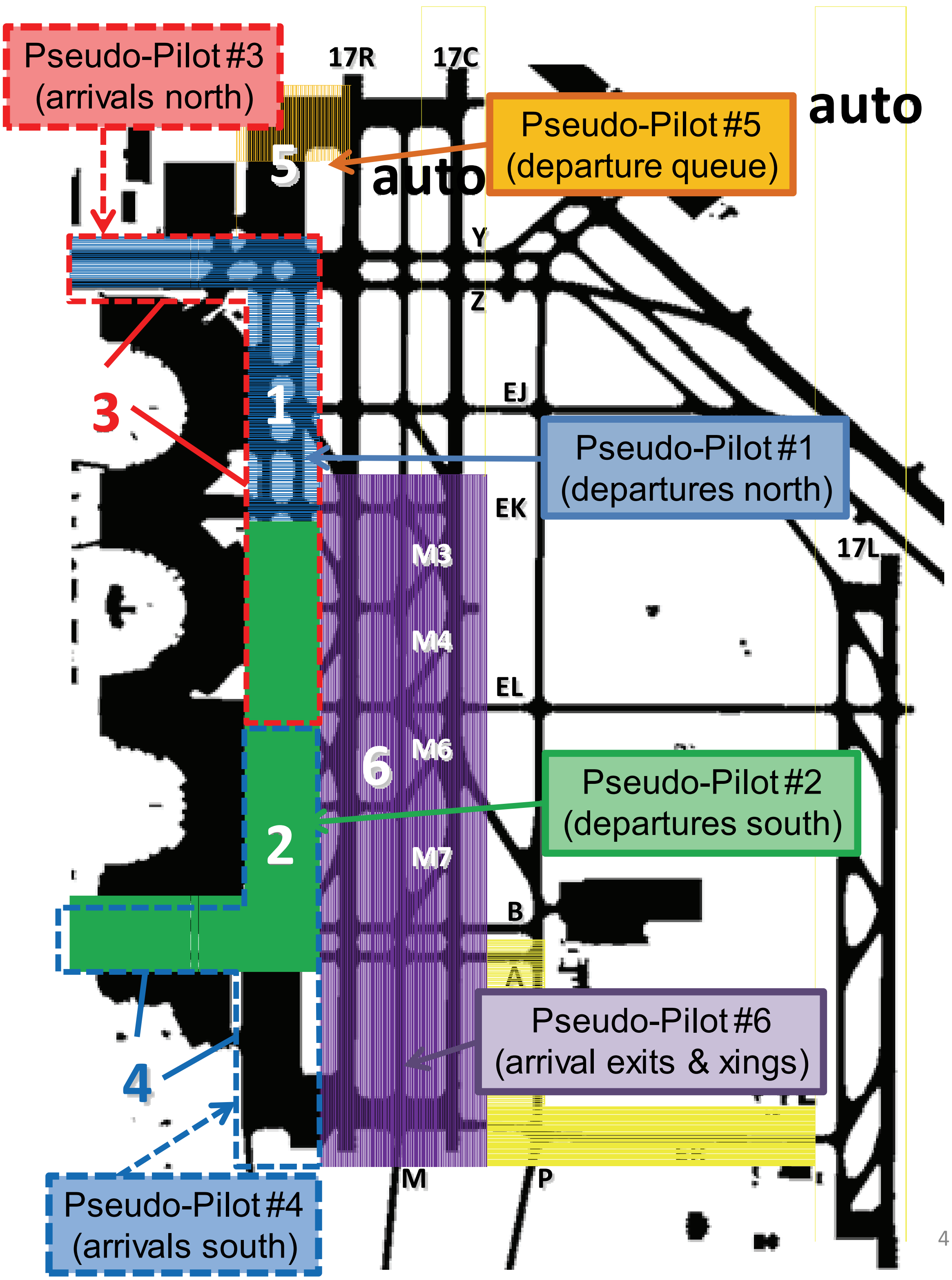
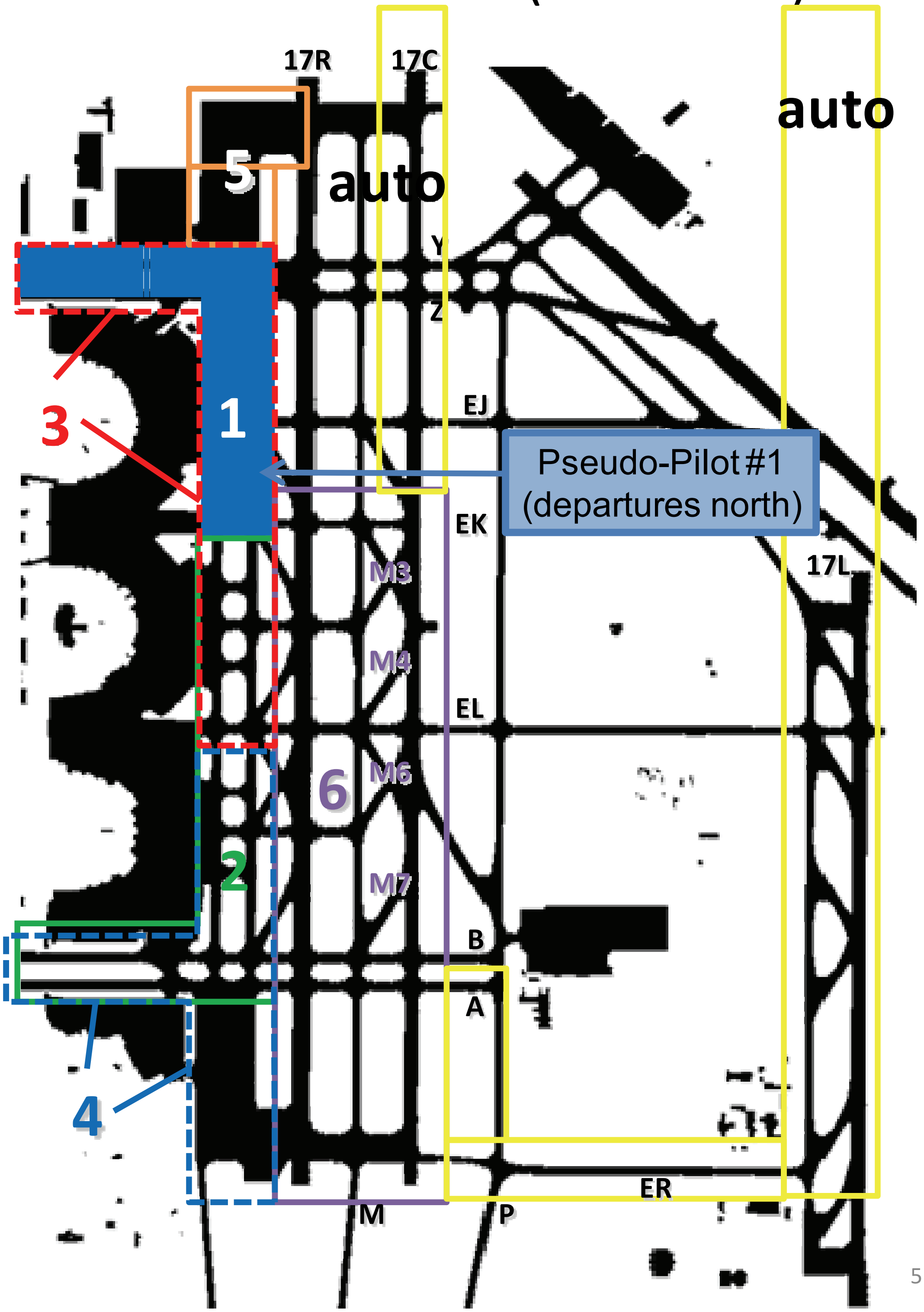
Magenta :	Automatic pilot spool-up in ramp
Yellow flashing :	Handoff initiated

Pilot Sectors (6 stations)



Pseudo-Pilot #1 (6 Stations)



Pseudo-Pilot #1 (6 Stations)

Roles and Responsibilities

(blue shaded area on map)

- Frequency: Ground 121.65.
- Control departures north of EK from spots 5–24.
- Aircraft will be automated from the gates and will be handed off to pseudo-pilot's control before they reach the spot. Do not take control of aircraft in ramp.
- Move aircraft from the spot to designated runway, along the path specified by the ground controller. This will either be the Full length (J->EF), Inner (K->EG), Outer (L->EH), or Bridge route (Z->18L).
- Handoffs:
  - Initiates
    - For aircraft going to 18L, route to Z westbound, then HO.
    - For 18L, initiate "speed 15" before handing off aircraft.
    - Use the *Page Up* key to initiate handoff to automatic pilot for 18L departures.
  - Accepts
    - Pseudo-pilot #2 should have initiated handoff of aircraft prior to reaching taxiway EK. If not, take control of aircraft once it crosses EK with *F2* key.

Pseudo-Pilot #1 (6 Stations)

Aircraft Control Actions

(blue shaded area on map)

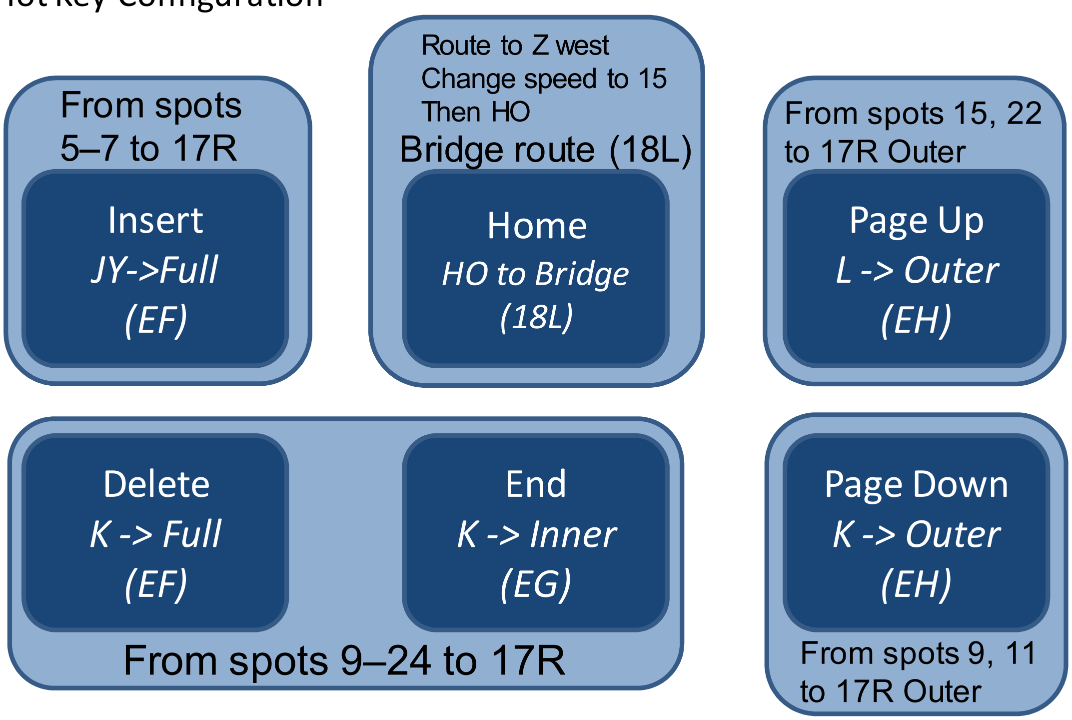
Objective

- Depart aircraft northbound from spots 5–24

Actions

- Sort Target List by callsign
- Select aircraft by clicking in Target List or on callsign on map
- Select taxi route from controller via hot keys
- Change aircraft speed to 15 knots via GPS Commander window: *Speed -> 15*
- Use the *F2* key to take control of aircraft after EK, if not already owned
- Additional commands entered via Cmd Text Entry window:
  - [flight ID] taxi JY/Zw for 18L via JY
  - [flight ID] taxi Kn/Zw for 18L via K

Hot Key Configuration



7

Pseudo-Pilot #2 (6 Stations)

8

Pseudo-Pilot #2 (6 Stations)

Roles and Responsibilities

(green shaded area on map)

- Frequency: Ground 121.65.
- Control departures south of EK from spots 31–53.
- Aircraft will be automated from the gates and will be handed off to pseudo-pilot's control before they reach the spot. Do not take control of aircraft in ramp.
- Move aircraft from the spot to designated runway, along the path specified by the ground controller. This will either be the Full length (K->EF), Inner (K->EG), Outer (K->EK->L->EH), or Bridge route (Z->18L).
- Use the *Page Up* key to set aircraft speed to 15 knots after assigning taxi path.
- Use the *Home* key to initiate handoff to pseudo-pilot #1 for flights to runway 17R or northern bridge (Z), after crossing taxiway EK.

Pseudo-Pilot #2 (6 Stations)

Aircraft Control Actions

(green shaded area on map)

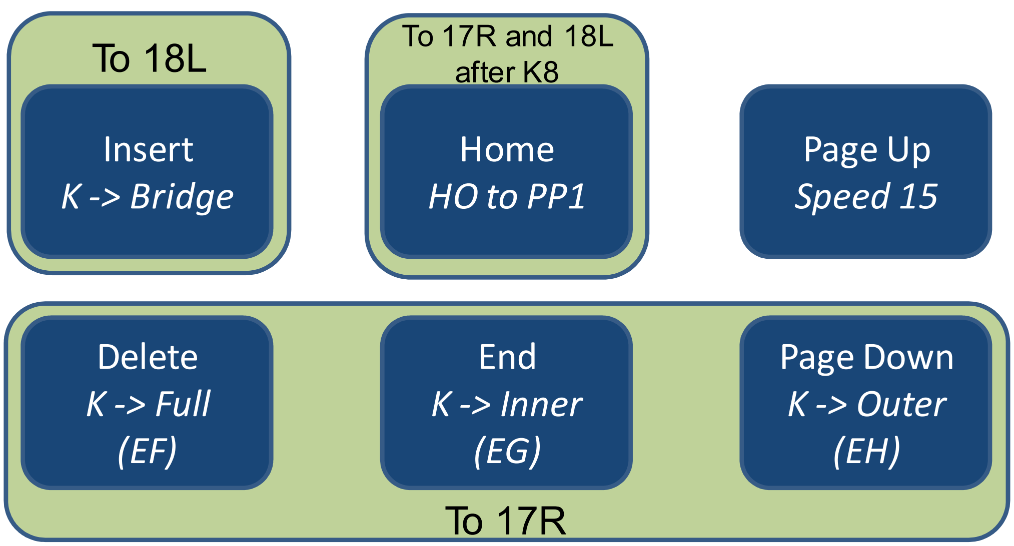
Objectives

- Depart aircraft northbound from spots 31–53

Actions

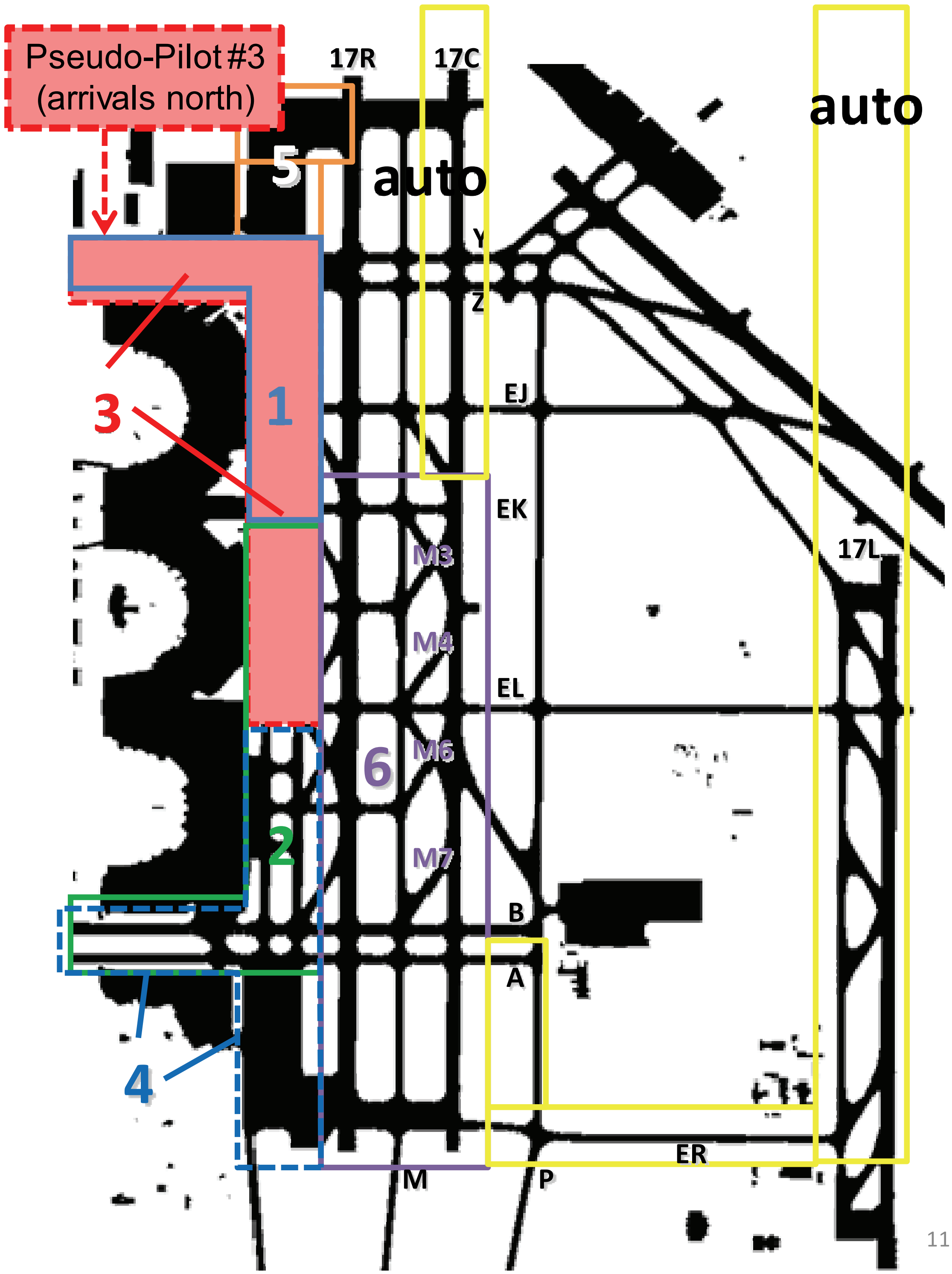
- Sort Target List by callsign
- Select aircraft by clicking in Target List or on callsign on map
- Select taxi route from controller via hot keys
- Change aircraft speed to 15 knots
- HO 17R and 18L aircraft to pseudo-pilot #1

Hot Key Configuration



10

Pseudo-Pilot #3



Pseudo-Pilot #3

Roles and Responsibilities

(red dashed area on map)

- Frequency: Ground 121.65.
- Control arrival aircraft from west side and other arrival aircraft parking in terminals A or C via spots 5-44 .
- Control arrival aircraft taxiing north of taxiway EL.
- Handoff aircraft arriving at spots 5-44 to gate automatic pilot. Do not control aircraft in ramp.
- Handoffs:
  - Initiates
    - Wait until aircraft is approaching the spot before handing off to gate automatic pilot.
    - For Terminal A gates, enter gate number xx and use the *End* key to handoff flight from spot to automatic pilot.
    - For Terminal C gates, enter gate number xx and use the *Page Down* key to handoff flight from spot to automatic pilot.
  - Accepts
    - From pseudo-pilot #4 if aircraft is entering terminal A or C via spots north of taxiway EL.
    - From pseudo-pilot #6 for aircraft crossing runway 17R on taxiways K8 or EL.
- Handoff nomenclature: 10X.ZZ/0
  - X = 0 for Terminal A, X = 1 for Terminal C, X = 2 for Terminal E
  - ZZ = gate number with 2 digits
  - *HO 100.09/0* is Terminal A, gate 9
  - *HO 101.12/0* is Terminal C, gate 12
  - *HO 102.21/0* is Terminal E, gate 25

Pseudo-Pilot #3

Aircraft Control Actions

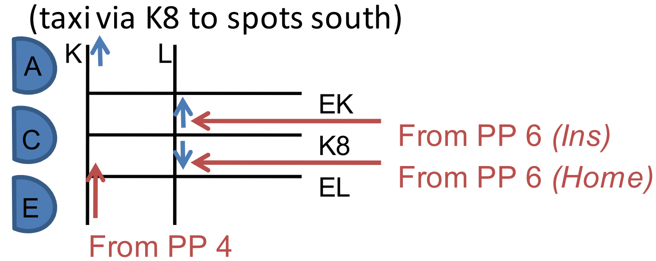
(red dashed area on map)

Objectives

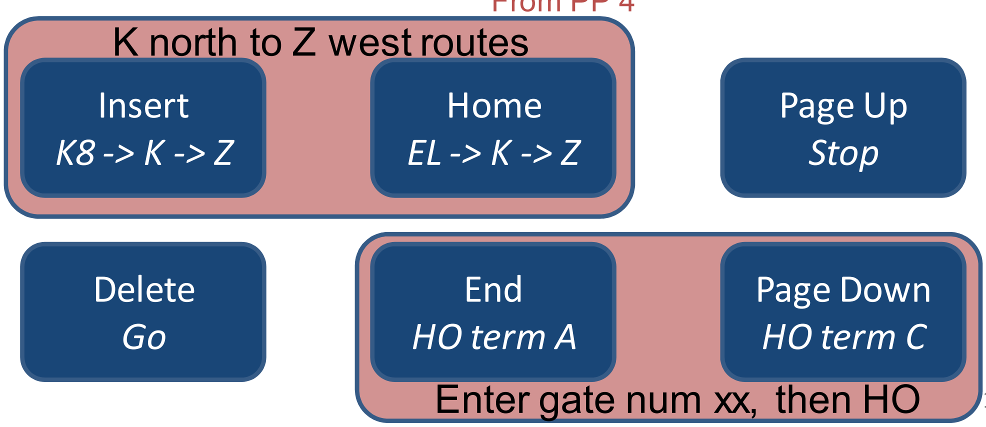
- Control arrivals to terminals A & C via spots 5-44
- Move aircraft from spot to gate
- Use K and L north of K8 for northbound traffic; use L south of K8 for southbound traffic

Actions

- Sort Target List by callsign
- Select aircraft by clicking in Target List or on callsign on map
- Select taxi route from controller via hot keys for arrivals going north on K to spots
- For flights to terminal A, enter gate number xx, then *End* key
- For flights to terminal C, enter gate number xx, then *Page Down* key
- Additional commands entered via Cmd Text Entry window:
    - [flight ID] taxi K8/Ls (taxi via K8 to spots south)

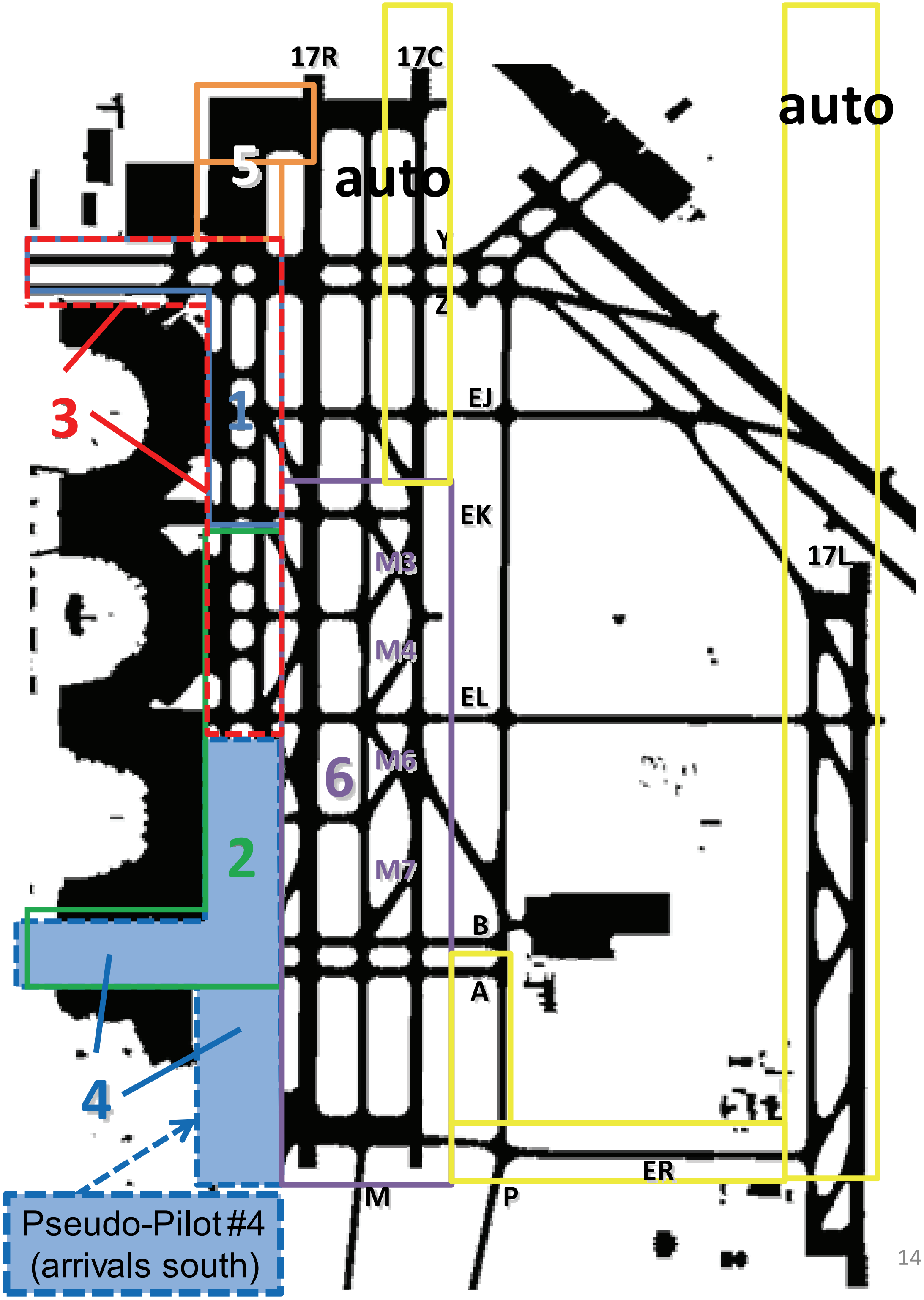


Hot Key Configuration



13

Pseudo-Pilot #4



Pseudo-Pilot #4

Roles and Responsibilities

(blue dashed area on map)

- Frequency: Ground 121.65.
- Control arrival aircraft from west side on taxiway A and other arrival aircraft parking in terminal E via spots 45–53.
- Control arrival aircraft taxiing between EL and ER, west of 17R.
- Handoff aircraft arriving at spots 45–53 to gate automatic pilot. Do not control aircraft in ramp.
- Handoffs:
  - Initiates
    - Enter gate number xx and use the *Page Down* key to handoff flight from spots 45–53 to automatic pilot for Terminal E gates.
    - Use the *End* key to handoff to pseudo-pilot #3 if aircraft is entering Terminal A or C north of and including taxiway EL.
  - Accepts
    - From pseudo-pilot #6 for aircraft crossing runway 17R on taxiway EM, B, A, or ER.
    - From automatic pilot for west side for arrivals traveling eastbound on taxiway A on south bridge.
- Handoff nomenclature: 10X.ZZ/0
  - X = 0 for Terminal A, X = 1 for Terminal C, X = 2 for Terminal E
  - ZZ = gate number with 2 digits
  - *HO 100.09/0* is Terminal A, gate 9
  - *HO 101.12/0* is Terminal C, gate 12
  - *HO 102.21/0* is Terminal E, gate 25

15

Pseudo-Pilot #4

Aircraft Control Actions

(blue dashed area on map)

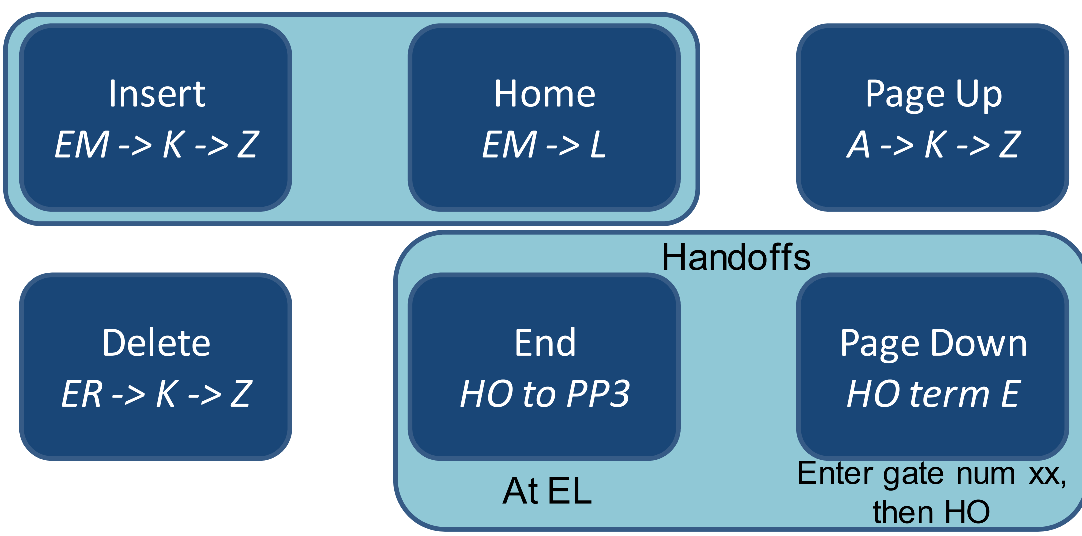
Objectives

- Control arrivals to Terminal E using spots 45–53
- Move aircraft from taxiway to spot, then HO to automatic gate pilot
- Use K for northbound traffic; Use L for southbound traffic

Actions

- Sort Target List by callsign
- Select aircraft by clicking in Target List or on callsign on map
- When flight reaches EL, use *End* key to handoff to PP#3
- Select route from controller via hot keys to move arrivals to spots
- For aircraft on EM, B, A, & ER, build route to assigned spot, then HO to automatic gate pilot
- For B->K, draw route to K, then use *Insert* key to move the aircraft on K, then select the spot
- For flights at spots 45–53, enter gate number xx and use the *Page Down* key to handoff flight to automatic gate pilot
- For flights at spot 53, build route to second node inside ramp area, then HO to automatic gate pilot

Hot Key Configuration

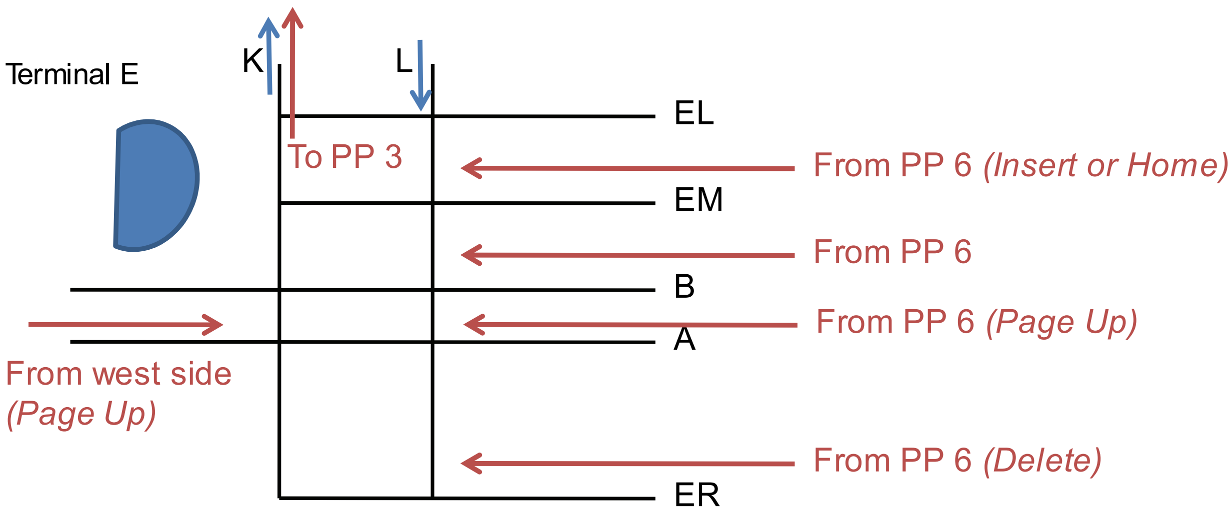


16

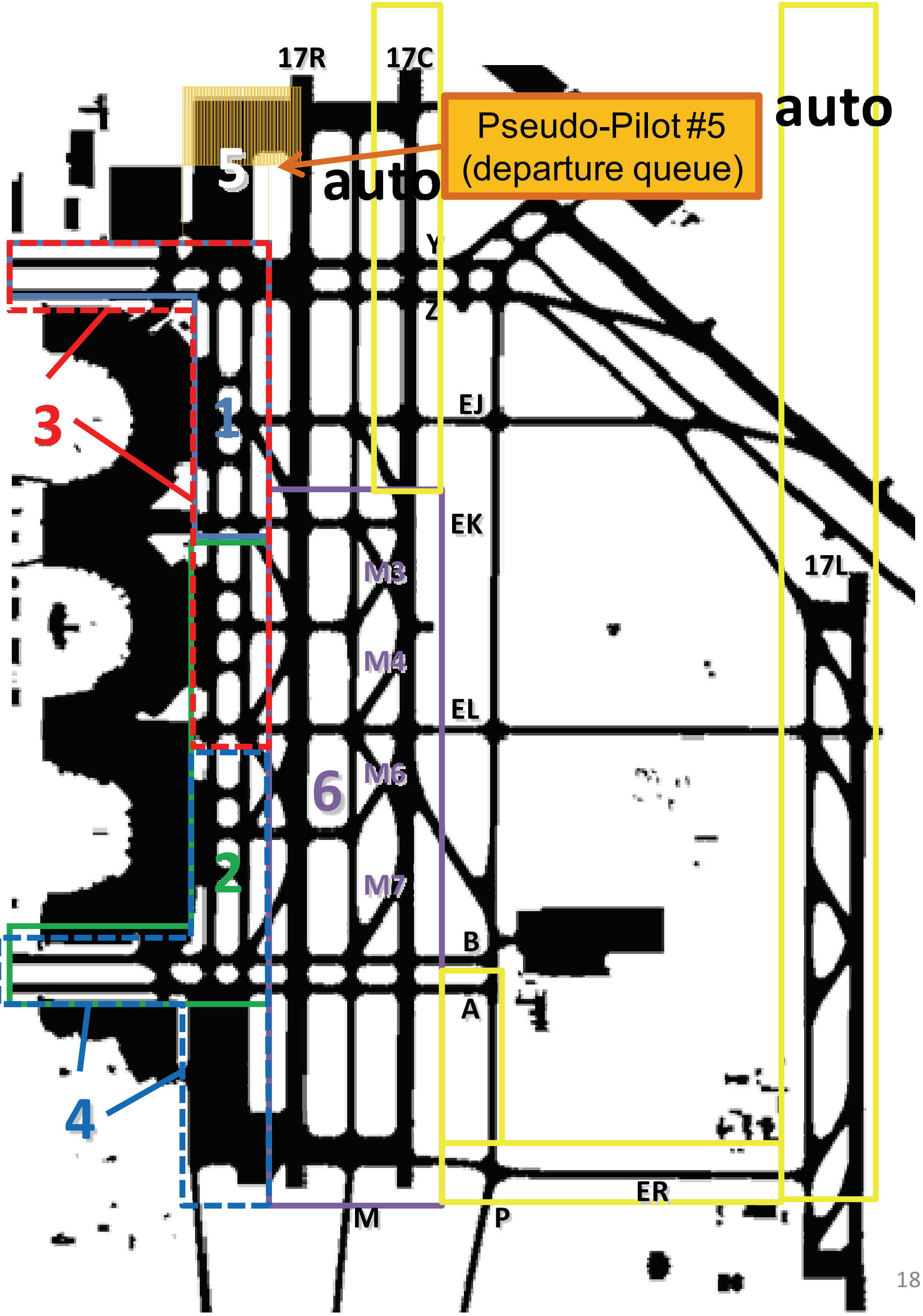
Pseudo-Pilot #4

Aircraft Control Actions

(blue dashed area on map)



Pseudo-Pilot #5



Pseudo-Pilot #5

Roles and Responsibilities

(orange shaded area on map)

- Frequency: Local 126.55.
- Controls aircraft departing on 17R.
- Use the *F2* key to take departure aircraft from pseudo-pilot #1 after crossing Y.
- Taxi route to departure queue (full, inner, outer) should have already been input by pseudo-pilot #1 or #2.
- Taxi in position hold (TIPH) for departure.
    - Use the *Insert* key to select TIPH at EF.
    - Use the *Home* key to select TIPH at EG.
    - Use the *Page Up* key to select TIPH at EH.
- Use the *Delete* key to depart aircraft on 17R when cleared by the local controller. This also performs HO to departure control frequency (this is automated to depart aircraft and remove after predefined time).

19

Pseudo-Pilot #5

Aircraft Control Actions

(orange shaded area on map)

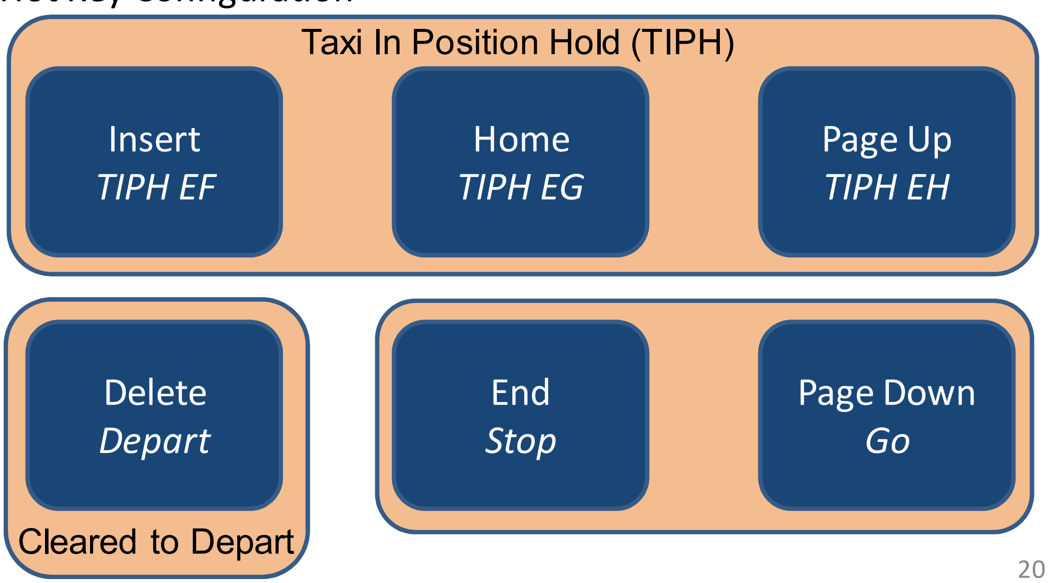
Objective

- Depart aircraft in queue to 17R

Actions

- Sort Target List by callsign
- Select aircraft by clicking in Target List or on callsign on map
- Use the *F2* key to take control of aircraft after taxiway Y
- Use *Insert, Home, Page Up* keys to position aircraft on runway for takeoff when directed by controller
- Use *Delete* key to depart aircraft when directed by controller

Hot Key Configuration



20

Pseudo-Pilot #6

21

Pseudo-Pilot #6

Roles and Responsibilities

(purple shaded area on map)

- Frequency: Local 126.55
- Control
  1) Arrivals landing on 17C
  2) Arrivals crossing 17R and 17C
- Take high speed exit as directed by local controller from 17C
  - Use the *Insert* key to select the M3 exit
  - Use the *Home* key to select the M4 exit
  - Use the *Page Up* key to select the M6 exit
  - Use the *Delete* key to select the M7 exit
  - Default is M3 for arrivals to Terminal A, M4 for arrivals to Terminal C, M7 for arrivals to Terminal E
- Cross runway 17R as directed by local controller for flights landing on 17C and handoff to PP#3 or PP#4
- Cross runway 17C as directed by local controller for flights on taxiways ER and A by building route to hold short of 17R
- Cross runway 17R as directed by local controller for flights on taxiways ER and A by building route to node past 17R and handoff to PP#4
- Handoffs:
  - Initiates
    - Use the *End* key to initiate handoff to pseudo-pilot #3 after issuing command to cross runway 17R on taxiways K8 or EL (for M3/M4)
    - Use the *Page Down* key to initiate handoff to pseudo-pilot #4 issuing command to cross runway 17R on taxiways EM, B, A, or ER (for M6/M7 and 17L arrivals)
  - Accepts
    - From automatic pilot for flights landing on 17C and 17L

Pseudo-Pilot #6

Aircraft Control Actions

(purple shaded area on map)

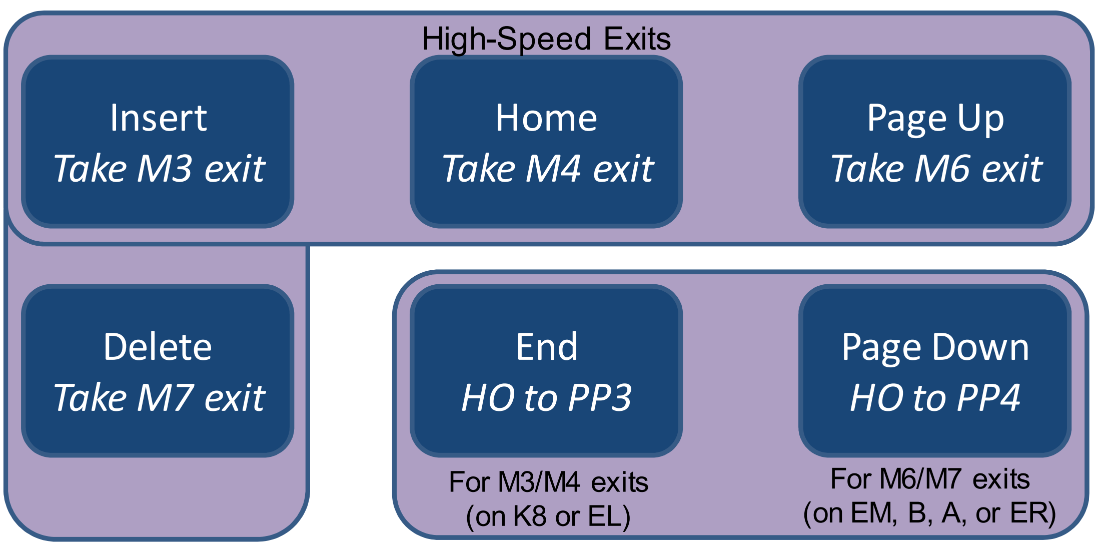
Objective

- Assign appropriate 17C runway exits per controller instructions
- Make corresponding runway 17R and 17C crossings per controller instructions

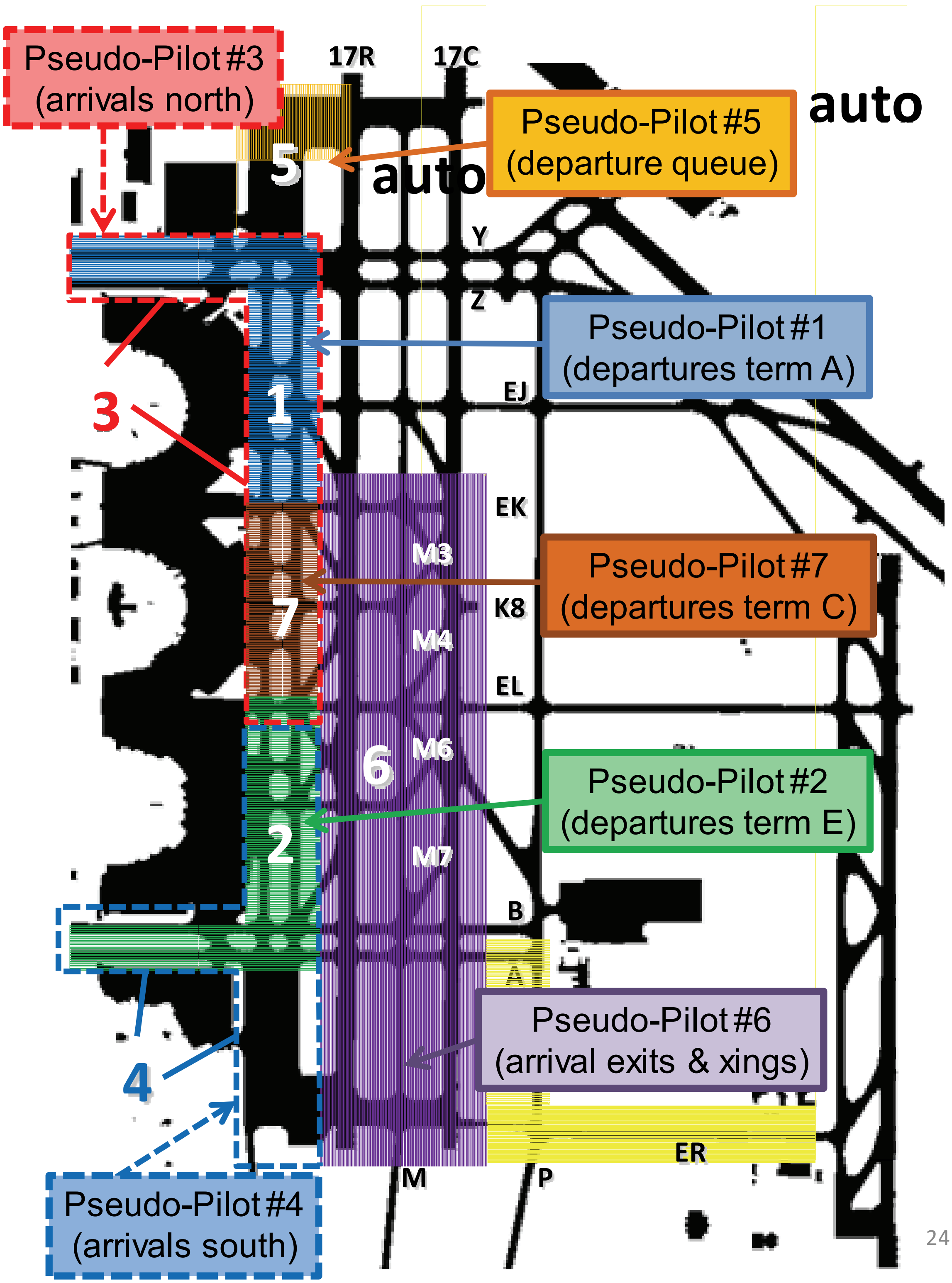
Actions

- Sort Target List by callsign
- Select aircraft by clicking in Target List or on callsign on map
- For 17R crossing, move aircraft one node after runway crossing and use *End* or *Page Down* key to handoff aircraft
- For flights westbound on ER or A, cross 17C by moving aircraft to node just short of 17R

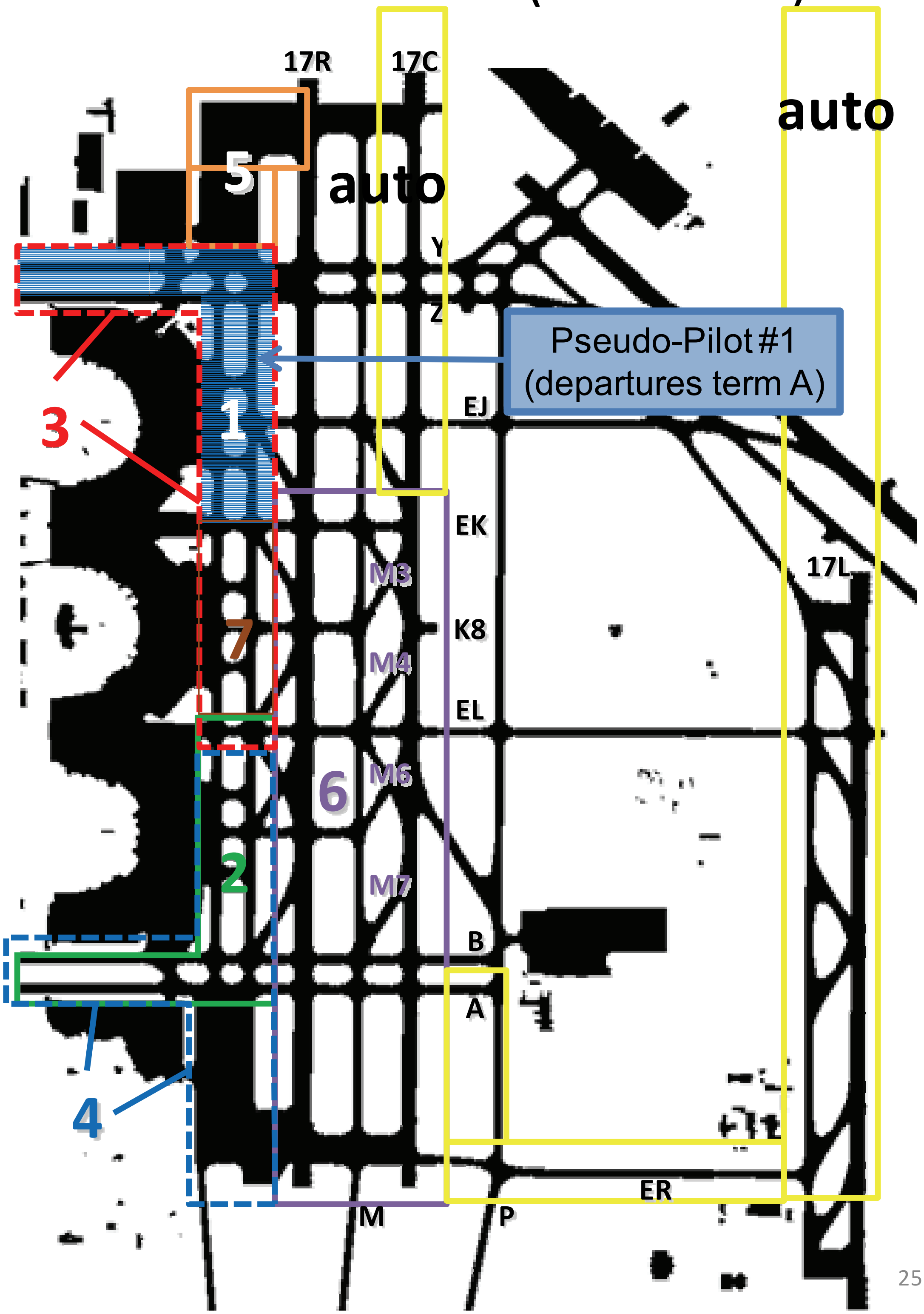
Hot Key Configuration



Pilot Sectors (7 Stations)



Pseudo-Pilot #1 (7 Stations)



25

Pseudo-Pilot #1 (7 Stations)

Roles and Responsibilities

(blue shaded area on map)

- Frequency: Ground 121.65.
- Control departures north of EK from spots 5–23.
- Aircraft will be automated from the gates and will be handed off to pseudo-pilot’s control before they reach the spot. Do not control aircraft in ramp.
- Move aircraft from the spot to designated runway, along the path specified by the ground controller. This will either be the Full length (J->EF), Inner (K->EG), Outer (L->EH), or Bridge route (Z->18L).
- Handoffs:
  - Initiates
    - For aircraft going to 18L, route to Z westbound, then HO.
    - For 18L, initiate “speed 15” before handing off aircraft.
    - Use the *Page Up* key to initiate handoff to automatic pilot for 18L departures.
  - Accepts
    - Pseudo-pilot #2 should have initiated handoff of aircraft prior to reaching taxiway EK. If not, take control of aircraft once it crosses EK with *F2* key.

26

Pseudo-Pilot #1 (7 Stations)

Aircraft Control Actions

(blue shaded area on map)

Objective

- Depart aircraft northbound from spots 5–23

Actions

- Sort Target List by callsign
- Select aircraft by clicking in Target List or on callsign on map
- Select taxi route from controller via hot keys
- Change aircraft speed to 15 knots via GPS Commander window: *Speed -> 15*
- Use the *F2* key to take control of aircraft after EK, if not already owned
- Additional commands entered via Cmd Text Entry window:
  - [flight ID] taxi JY/Zw   for 18L via JY
  - [flight ID] taxi Kn/Zw   for 18L via K

Hot Key Configuration

From spots 5–7 to 17R

Insert
JY->Full
(EF)

Home
JY -> Inner
(EG)

Route to Z west
Change speed to 15
Then HO

Bridge route (18L)

Page Up
HO to Bridge
(18L)

Delete
K -> Full
(EF)

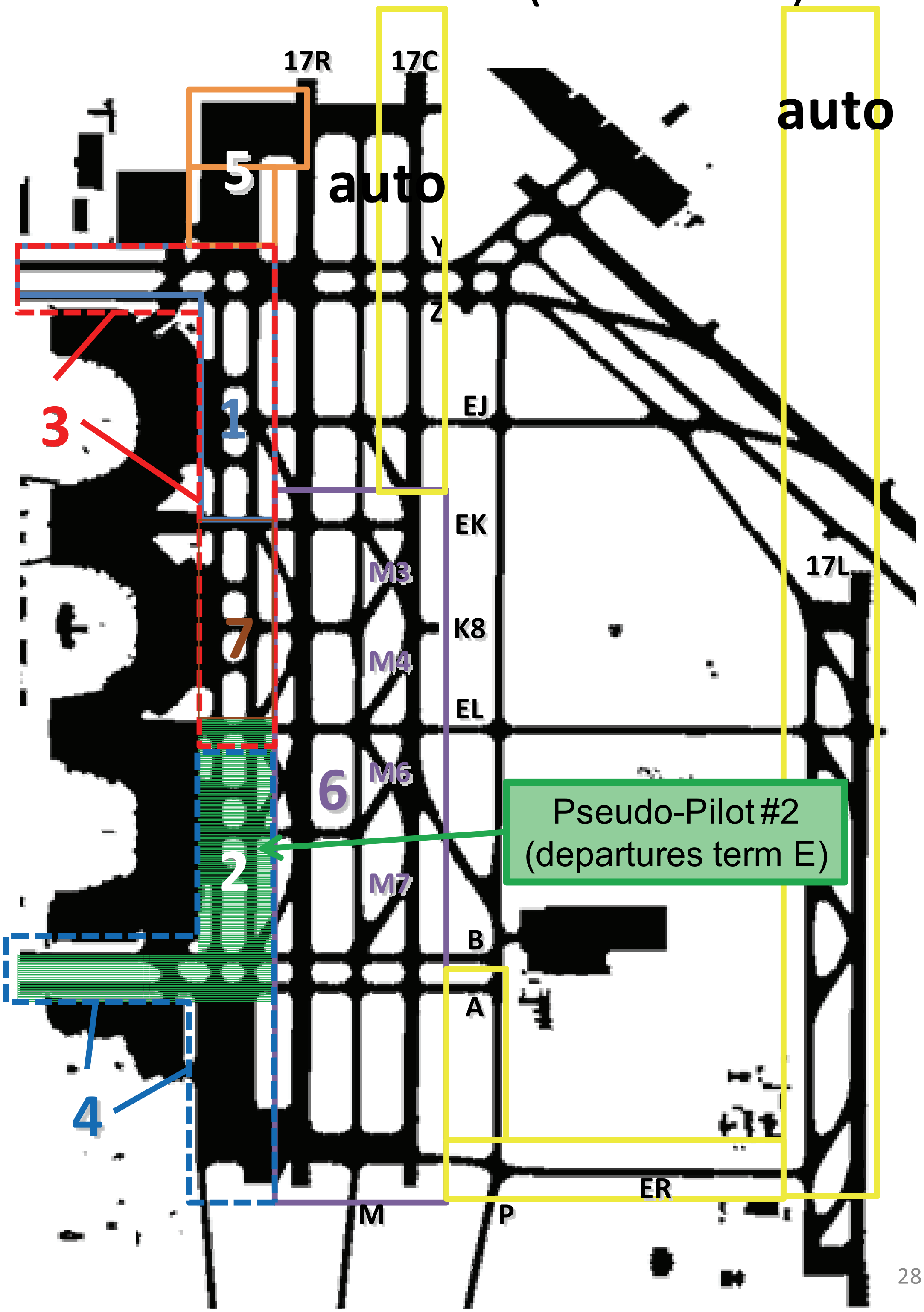
End
K -> Inner
(EG)

Page Down
K -> Outer
(EH)

From spots 9–23 to 17R

27

Pseudo-Pilot #2 (7 Stations)



28

Pseudo-Pilot #2 (7 Stations)

Roles and Responsibilities

(green shaded area on map)

- Frequency: Ground 121.65.
- Control departures south of EL from spots 42–53.
- Aircraft will be automated from the gates and will be handed off to pseudo-pilot's control before they reach the spot. Do not control aircraft in ramp.
- Move aircraft from the spot to designated runway, along the path specified by the ground controller. This will either be the Full length (K->EF), Inner (K->EG), Outer (K->EH), or Bridge route (Z->18L).
- Use the *Page Up* key to set aircraft speed to 15 knots after assigning taxi path.
- Use the *Home* key to initiate handoff to pseudo-pilot # 7 for flights to runway 17R or northern bridge (Z), after crossing taxiway EL.

Pseudo-Pilot #2 (7 Stations)

Aircraft Control Actions

(green shaded area on map)

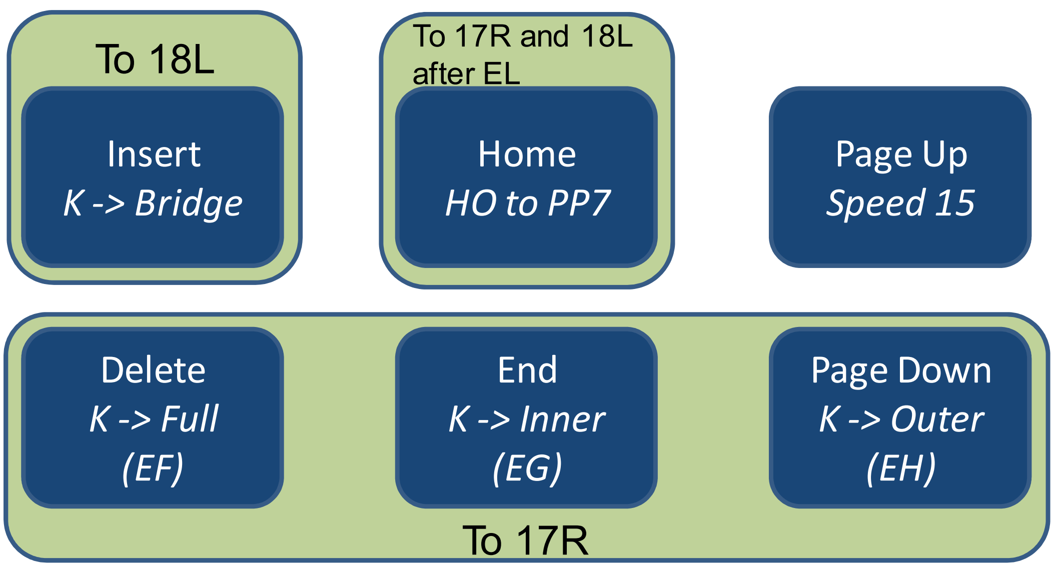
Objectives

- Depart aircraft northbound from spots 42–53

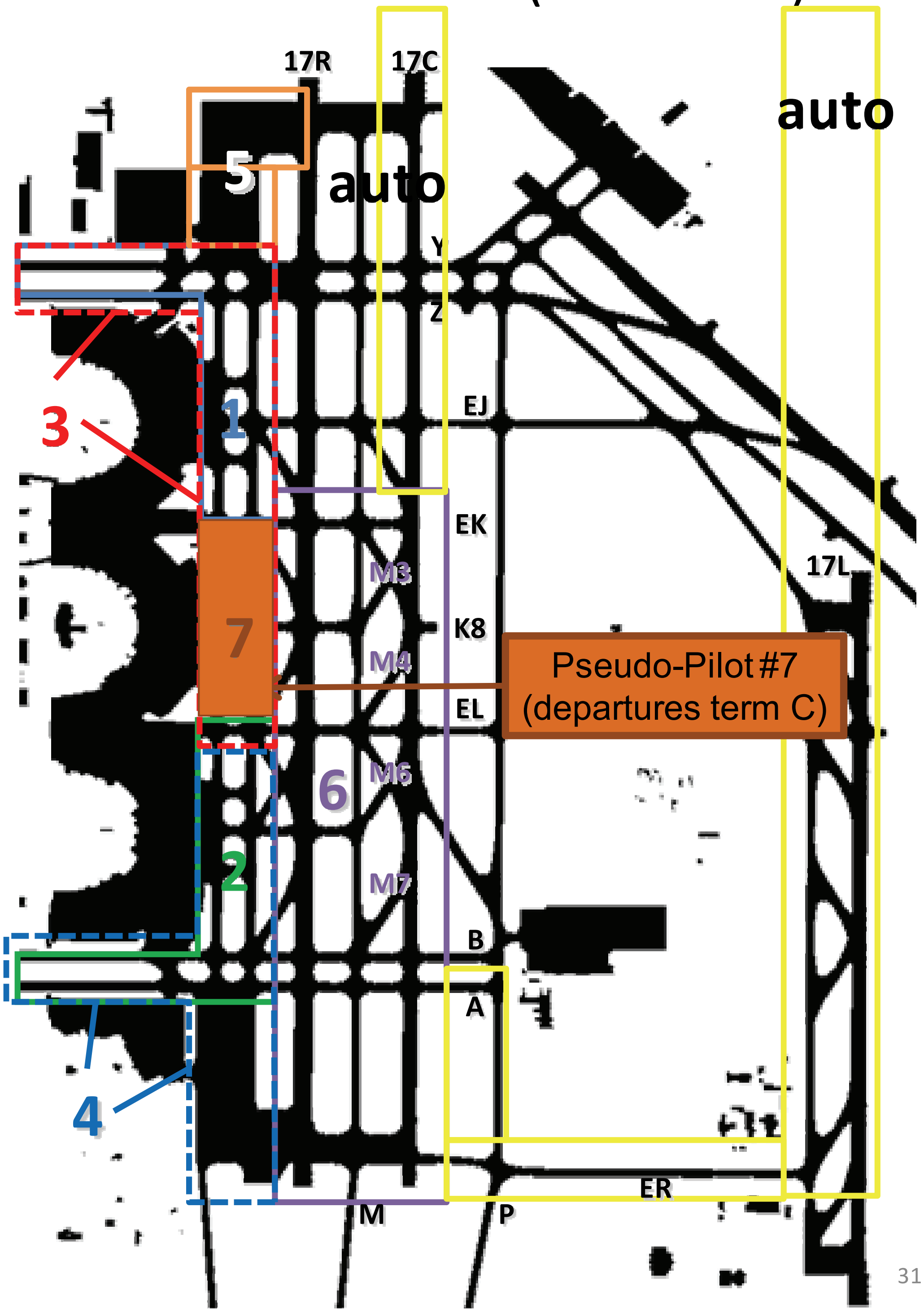
Actions

- Sort Target List by callsign
- Select aircraft by clicking in Target List or on callsign on map
- Select taxi route from controller via hot keys
- Change aircraft speed to 15 knots
- HO 17R and 18L aircraft to pseudo-pilot #7

Hot Key Configuration



Pseudo-Pilot #7 (7 Stations)



Pseudo-Pilot #7 (7 Stations)

Roles and Responsibilities

(brown shaded area on map)

- Frequency: Ground 121.65.
- Control departures out of terminal C from spots 24–41.
- Aircraft will be automated from the gates and will be handed off to pseudo-pilot's control before they reach the spot. Do not control aircraft in ramp.
- Move aircraft from the spot to designated runway, along the path specified by the ground controller. This will either be the Full length (K->EF), Inner (K->EG), Outer (K->EH), or Bridge route (Z->18L).
- Use the *Page Up* key to set aircraft speed to 15 knots after assigning taxi path.
- Use the *Home* key to initiate handoff to pseudo-pilot #1 for flights to runway 17R or northern bridge (Z), after crossing taxiway EK.

Pseudo-Pilot #7 (7 Stations)

Aircraft Control Actions

(brown shaded area on map)

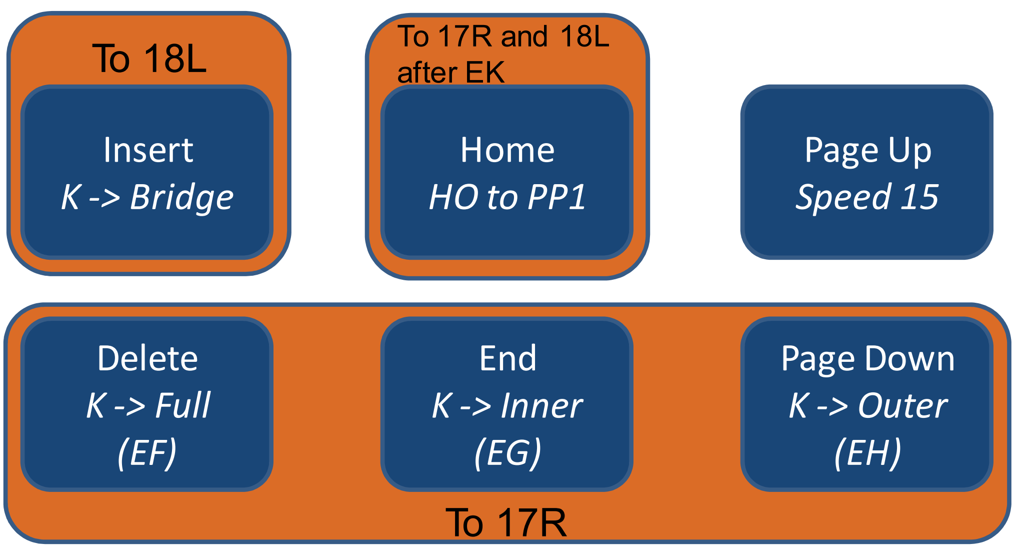
Objectives

- Depart aircraft northbound from spots 24–41

Actions

- Sort Target List by callsign
- Select aircraft by clicking in Target List or on callsign on map
- Select taxi route from controller via hot keys
- Change aircraft speed to 15 knots
- HO 17R and 18L aircraft to pseudo-pilot #1

Hot Key Configuration



33

APPENDIX E: SCENARIO DEVELOPMENT

Scenario Generation Using Matlab

For evaluation of proposed concepts and advisories, "scenarios" of traffic are a critical component. It is important that these scenarios are based on actual operations at Dallas/Fort Worth (DFW) airport. A Matlab-based infrastructure was developed to facilitate the development of these scenarios, with many of its components being based on historical statistics obtained from Surface Operations Data Analysis and Adaptation (SODAA).[1]

Note: The parameter files (text files ending in 'txt') mentioned here are used as inputs by the Matlab m-files (e.g., WeightClassPercentages.txt).

The scenarios produced from the Matlab scripts are in a format appropriate for input to Airspace Traffic Generator (ATG) (see *Appendix G: ATG Scenario Files for April 2010 Simulations*). The scenarios were generated for a south-flow configuration, with departures on 17R and 18L and arrivals on 17C, 17L, 18R, and 13L. Three types of scenarios can be generated depending on the requirements:

- **Type 1 Scenarios** are a duplicate of an actual day (or partial day) at DFW airport. Data is collected using SODAA and run through Matlab scripts to create a scenario file that closely resembles the operations collected using SODAA.

- **Type 2 Scenarios** use seed day data from DFW airport collected using SODAA. The trends (airport departure and arrival rates throughout the day) are used to create scenarios, scaling up to five times the traffic level of the seed traffic. DFW airport usage statistics collected using SODAA are used to assign starting locations and destinations for the flights throughout the scenario.

- **Type 3 Scenarios** are created from user inputs of number of aircraft, scenario length, and airport trends. The trends (airport departure and arrival rates throughout the day) are used with DFW airport usage statistics collected using SODAA to assign starting locations and destinations for the flights throughout the scenario.

For the SARDA simulations, "Type 3 Scenarios" were used. The user inputs required were

a. Number of departures
b. Number of arrivals
c. Departure loading
d. Arrival loading
e. Simulation time (seconds)

[1] Mosaic ATM Inc.: User's Guide, version 2.7.0, Sept. 9, 2011.
http://sodda.mosaicatm.com/sodaa_current/sodaasite/SODAA_User_Guide.pdf

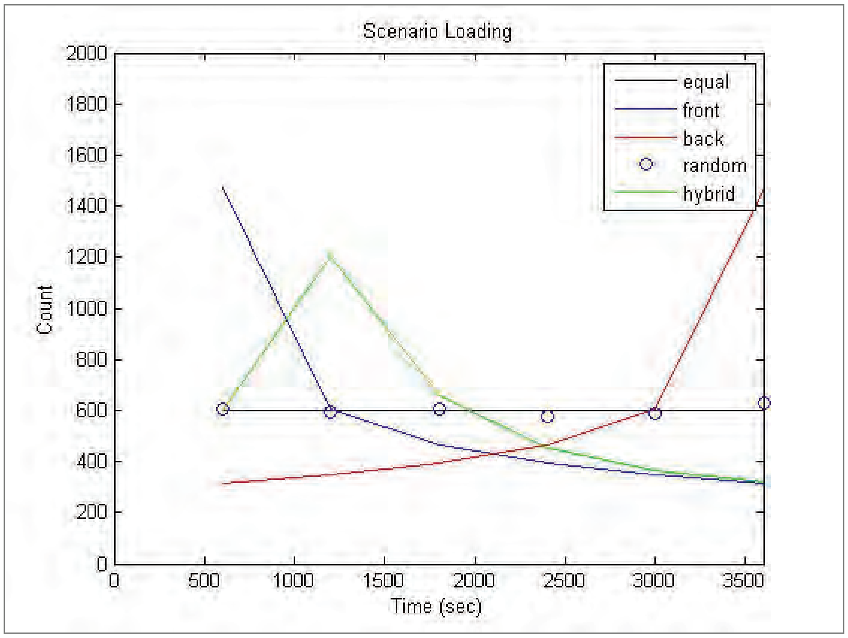


Figure E1: Sample traffic loading profiles.

User inputs (c) and (d) determines how the flights are scattered throughout the scenario. There are five different options for the loading parameter: equal, front, back, random, and hybrid. The hybrid option uses a combination of the other four loading characteristics. Figure E1 shows all five options: the larger the count, the more flights there are in that time frame. For example, a front-loaded scenario will have more flights scheduled near the start of the scenario, while back loading results in more flights scheduled near the end of the scenario.

There are various files that provide historical statistics collected through SODAA, and these provide the following essential information necessary for the scenario generation (see *Appendix F: Historical Input Files for Scenario Generation*).

Weight Classes: The text file "*WeightClassPercentages.txt*" determines the mix of weight classes in the scenario.

Spots: The text file "*SpotPercentages.txt*" determines the mix of spots used, as well as what category (arrival or departure) can use them. There are some spots that are labeled "Large Only." You will not find these in the text file, only in the m-file. This was done after the December Simulation, where it was found that Heavy's and B757's should not go to some spots. The reason for this is that a Heavy or B757 will collide with aircraft that are using adjacent spots.

Runways: Runways are determined according to the text files "*DepartureRunwayPercentages.txt*" and "*ArrivalRunwayPercentages.txt.*" The runway is assigned with respect to the flight's weight class and spot location/destination. For example, if a Heavy is located on the east side of DFW, it is 85 percent likely to be assigned runway 17R for departure.

Arrival Spacing: Arrival flights are separated on the runway according to a value for runway occupancy time. Runway occupancy times were found for various aircraft types on each arrival runway. The largest value for runway occupancy time was used as the separation value. This ensures that no flight will be scheduled to land while another flight occupies the runway.

Gate Clear Time: The estimated time it takes a departure flight to push back and clear the gate area so that an arrival flight can come in to park.

Turnaround Time: The time from when an arrival flight parks at a gate to when it is ready to push back for departure.

Aircraft Type: Aircraft types are assigned according to data collected at DFW airport using SODAA. Using the flight's weight class, an aircraft type is assigned according to the percentages in the following files:

"*SmallTypePercentages.txt*"
"*LargeTypePercentages.txt*"
"*HeavyTypePercentages.txt*"
"*B757TypePercentages.txt*"

Call Signs: Flight Call Signs are assigned according to the aircraft type, and the gate location. The Excel File "*CallSigns.xlsx*" can be modified to include more Airline/Aircraft Type Combinations. Terminals A and C are reserved for American (AAL) and Eagle Flight (EGF). All other airlines are scheduled in Terminal E.

Departure Fixes and Destinations: These are assigned with respect to the flight's runway assignment according to the following text files:

"*DepartureFixPercentages17R.txt*"
"*DepartureFixPercentages18L.txt*"
"*Runway17RDestinations.txt*"
"*Runway18LDestinations.txt*"

Four scenarios were generated for the April SARDA simulations with the following user inputs:
Normal 1: 40 departures, 40 arrivals, hybrid departure loading, equal arrival loading, 2600 seconds.
Normal 2: 40 departures, 40 arrivals, hybrid departure loading, equal arrival loading, 2600 seconds.
Heavy 1: 64 departures, 60 arrivals, hybrid departure loading, equal arrival loading, 2600 seconds.
Heavy 2: 64 departures, 60 arrivals, hybrid departure loading, equal arrival loading, 2600 seconds.

Figures E2 through E5 display the airport arrival and departure rates, and the departure runway usage for the respective scenarios.

Normal 1:

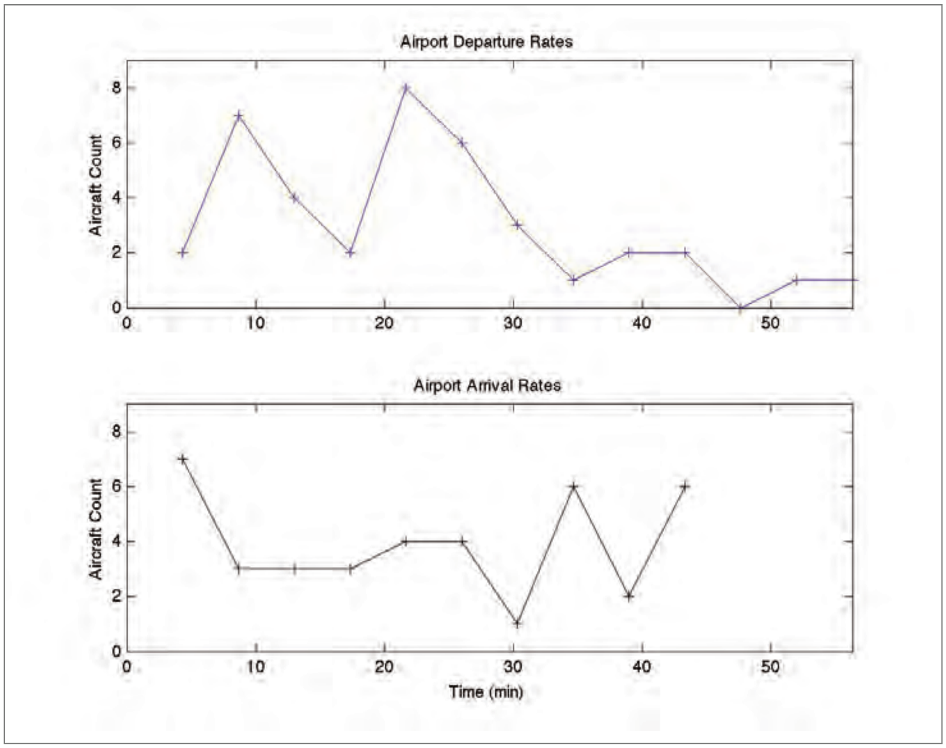


Figure E2a: Normal 1, Departure/Arrival Rates.

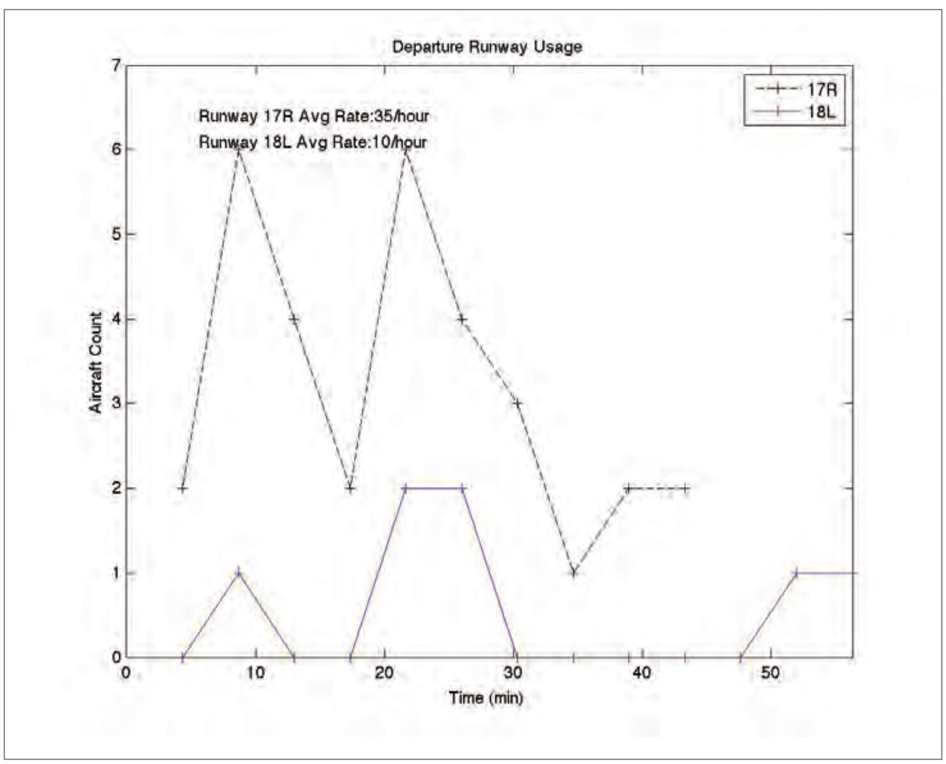


Figure E2b: Normal 1, Departure Runway Usage.

Normal 2:

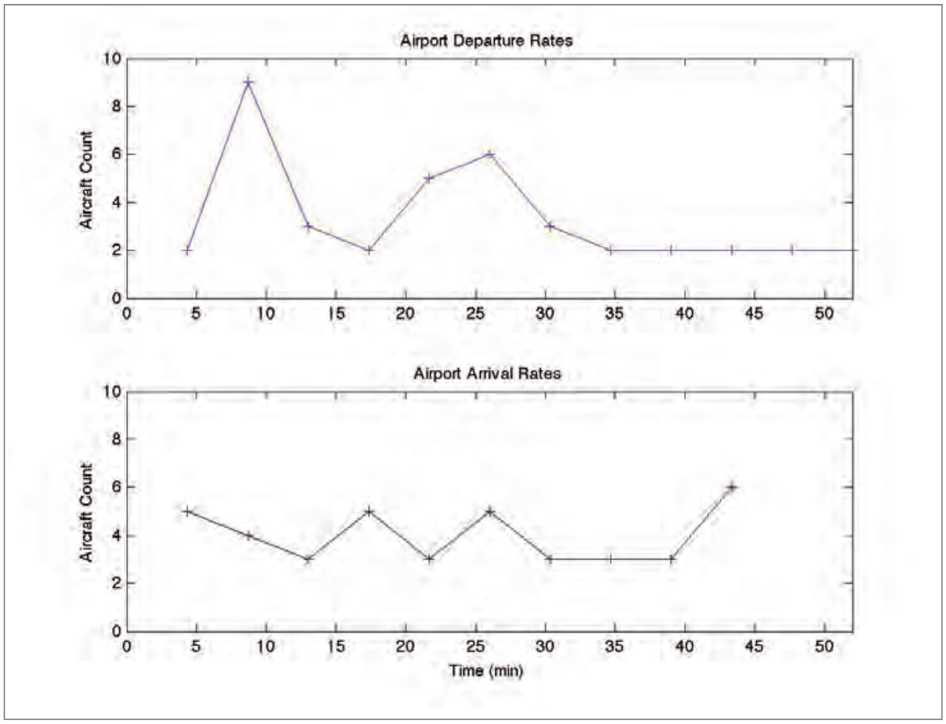


Figure E3a: Normal 2, Departure/Arrival Rates.

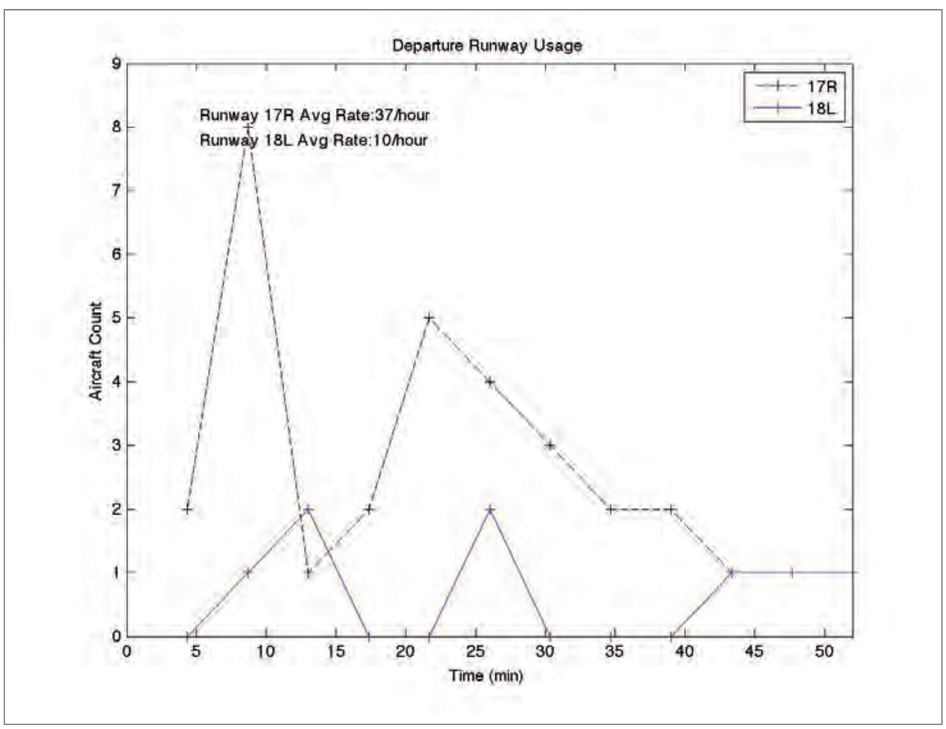


Figure E3b: Normal 2, Departure Runway Usage.

Heavy 1:

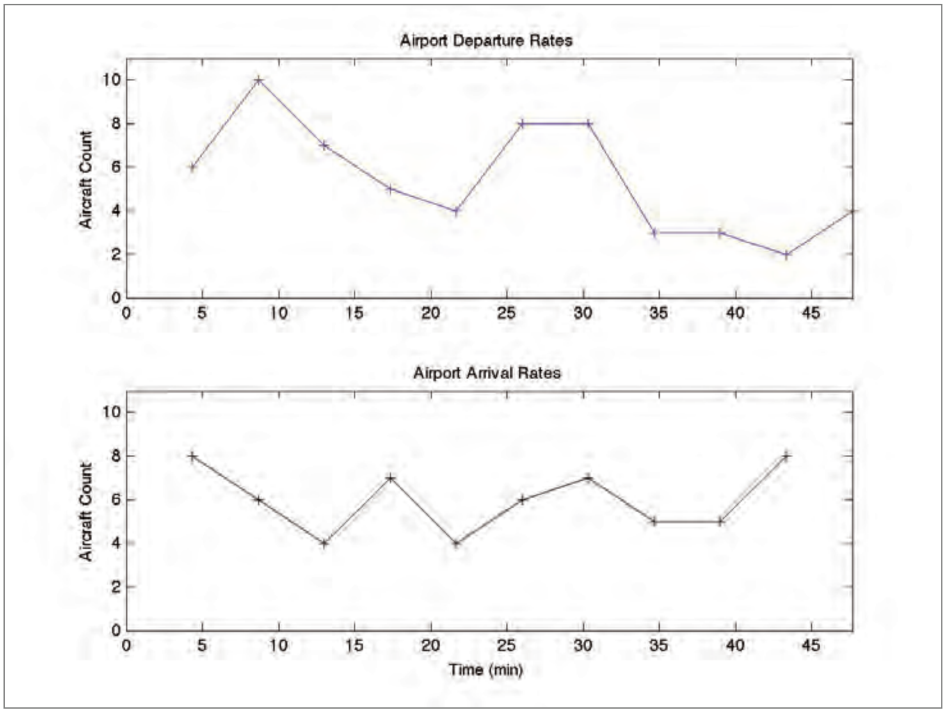


Figure E4a: Heavy 1, Airport Departure/Arrival Rate.

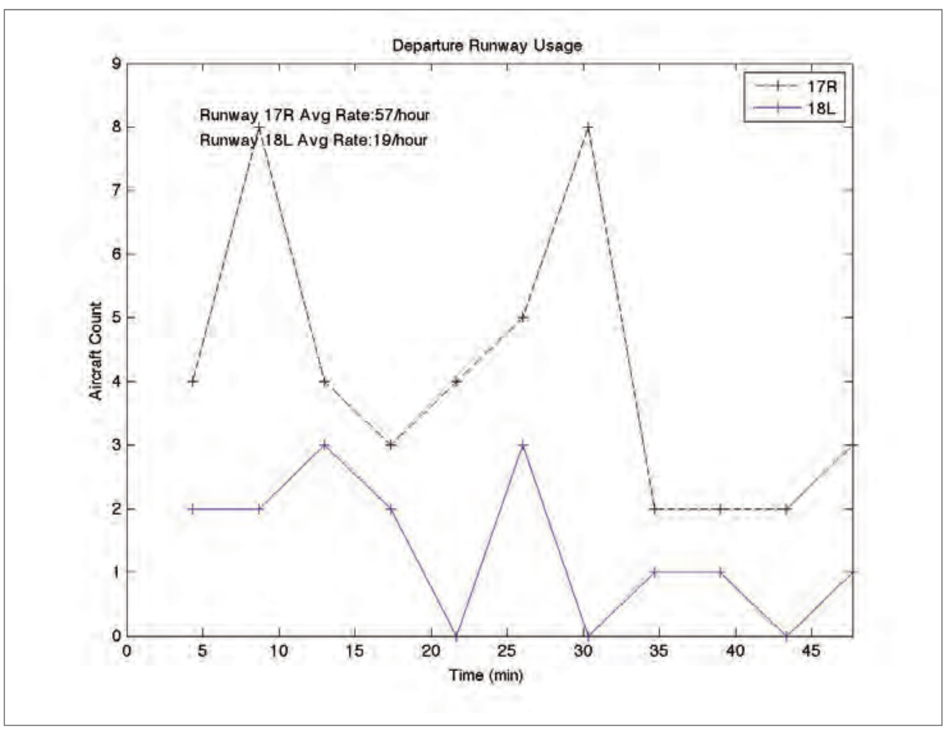


Figure E4b: Heavy 1, Departure Runway Usage.

Heavy 2:

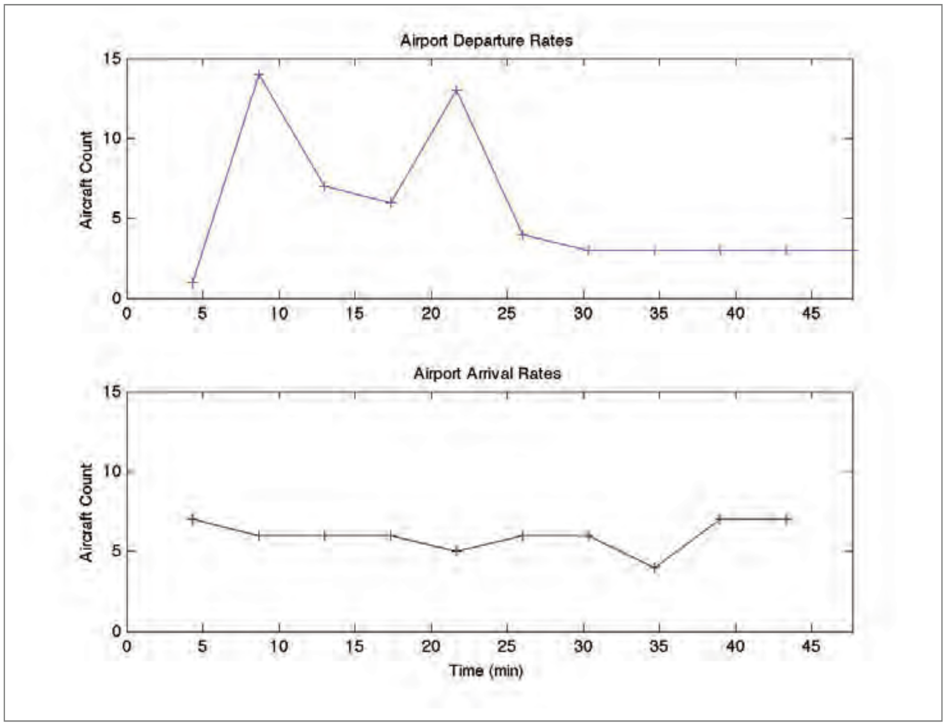


Figure E5a: Heavy 2, Airport Departure/Arrival Rate.

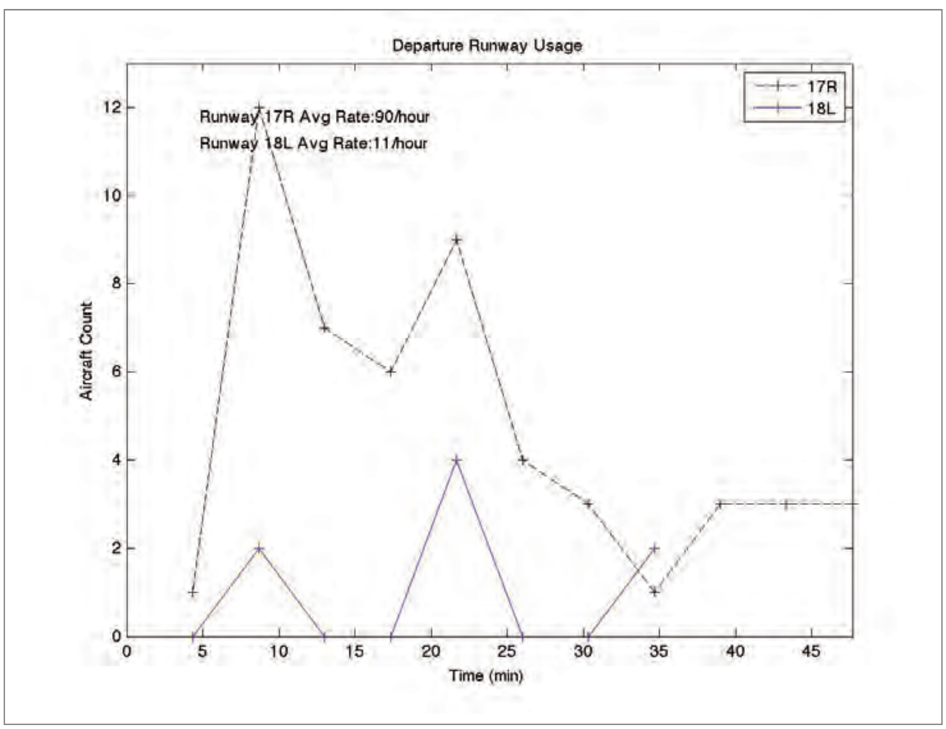


Figure E5b: Heavy 2, Departure Runway Usage.

Matlab Script Files

Listed here are two Matlab files used to create the Type 3 scenario files. The MASTER_Type3 script calls the ScenarioGeneratorType3 script to create the scenario files.

MASTER_Type3.m

```
% Type 3 Scenarios
%
% Create Scenarios based on user input data. This scenario generator will
% create a scenario based on user input trends as well as airport usage
% statistics gathered using SODAA.
clear all;close all;clc
% Path: This should be the location of the matlab files
% path(path,strcat('C:\Documents and Settings\mkistler\',...
%     'My Documents\SESO\SARDA\Scenario Generation\mfiles\mfiles_Type1'))
% Directory: This is the location of the data file collected using SODAA.
% It will also be where the scenarios are created
% cd(strcat('C:\Documents and Settings\mkistler\My Documents\',...
%     'SESO\SARDA\Scenario Generation\Scenarios_testing'))
%% User options - Loading
% front
% back
% equal
% random
% hybrid (equal + front)
%% User Inputs
NumDepartures=50;
NumArrivals=50;
DepLoading='hybrid2';
ArrLoading='hybrid';
SimTime=2900; %seconds
for i=1:length(NumDepartures)
    ScenarioGeneratorType3(NumDepartures(i),NumArrivals(i),...
        DepLoading,ArrLoading,SimTime)
end
```

ScenarioGeneratorType3.m

```
function ScenarioGeneratorType3(NumDepartures,NumArrivals,...
    DepLoading,ArrLoading,SimTime)

%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
% function ScenarioGeneratorType3(NumDeparture,NumArrivals,ArrLoading,...
%   DepLoading,SimTime)
%
%       This function contains all the necessary functions for creating a
%       scenario that can be run in SOSS or ATG/SMS. It will output a SOSS
%       scenario file, and an ATG scenario file. Both files will be named
%       according to the inputs (Number Arrivals, etc.) along with a time
%       stamp referring to when the scenario was created.
%
%   INPUTS:
%
%       NumDepartures: The number of departure flights the user wants to
%       schedule for the length of the scenario
```

```
%
%       NumArrivals: The number of arrival flights the user wants to
%       schedule for the length of the scenario
%
%       DepLoading: This specifies where the departure flights will be
%       scheduled in the scenario. The options are:
%               - front  : represents a departure push near the start of the
%               scenario
%               - back   : represents a departure push near the end of the
%               scenario
%               - equal  : departure flights are spread out equally in the
%               scenario
%               - random : departure flights are randomized throughout the
%               scenario
%               - hybrid : this is a combination of front and equal
%               loading, where the scenario starts out equal, then a
%               departure push happens near the middle of the scenario
%
%       ArrLoading: This specifies where the arrival flights will be
%       scheduled in the scenario. The options are:
%               - front  : represents an arrival push near the start of the
%               scenario
%               - back   : represents an arrival push near the end of the
%               scenario
%               - equal  : arrival flights are spread out equally in the
%               scenario
%               - random : arrival flights are randomized throughout the
%               scenario
%               - hybrid : this is a combination of front and equal
%               loading, where the scenario starts out equal, then an
%               arrival push happens near the middle of the scenario
%
%
%       SimTime: The length of the scenario, in seconds
%
% created by: Matthew Kistler (12/28/2009)
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%

%% Creating Dates and Directories
newDate = datestr(now,30);
% Create a new directory to place debug prints in
newDir = strcat('Reference_',newDate);
% mkdir(newDir)
%% Calculate Total Number of Flights
% Simple addition from the input number of arrivals and departures
NumAircraft=NumDepartures+NumArrivals;
%% Category
% Departures = 0, Arrivals = 1
Cat=[zeros(NumDepartures,1);ones(NumArrivals,1)];
%% Weight Class
% Weight class is assigned to each flight based on percentages found in
% the text file 'WeightClassPercentages.txt'. This file can be manipulated
% by the user to result in any distribution of weight classes. The four
% types of weight class used are Small (1), Large (2), B757 (3), and Heavy
% (4). Weight Class does not depend on the Category of the flight.
WC=WeightClassFinder(NumAircraft);
%% Spot
```

```
% Spot is assigned to each flight based on percentages found in the text
% file 'SpotPercentages.txt'. This file can be manipulated by the user to
% result in any distribution of spots according to category type. Currently
% Spots are assigned to be used only by arrival aircraft, or only by
% departure aircraft.
[Spt_ATG Spt_SOSS]=SpotFinder2(NumAircraft,Cat,WC);
%% Runway
% Runways are assigned for arrival and departure flights based on different
% criteria specified in the text files 'ArrivalRunwayPercentages.txt' and
% 'DepartureRunwayPercentages.txt'. A runway is determined for each flight
% based on the flight's spot, weight class, and category.
Rnwy=RunwayFinder2(Spt_SOSS,WC,Cat,'SOS')';
%% Flight ID
% A flightID is assigned to each flight to keep track of it more easily
% throughout this code.
FID=1:1:NumAircraft;
FID=FID(:);
%% Create Flight Schedule
% Empty Values
Gate=NaN*ones(length(FID),1);
InTime=NaN*ones(length(FID),1);
OutTime=NaN*ones(length(FID),1);
OnTime=NaN*ones(length(FID),1);
OffTime=NaN*ones(length(FID),1);
SpotTime=NaN*ones(length(FID),1);
% Combine Empty Values with Known Values
FlightSchedule=[FID(:) Cat(:) WC(:) Gate(:) Spt_SOSS(:)...
    Rnwy(:) InTime(:) OutTime(:) OnTime(:) OffTime(:) SpotTime(:)...
    Spt_ATG(:)];
%% Assign Activation Times
FlightSchedule = AssignActivationTimes(FlightSchedule,ArrLoading,...
    DepLoading,SimTime,3);
%% Scheduler
% Assign repeater values. These will continue the scheduling functions if
% errors are found.
repeatArrSpacer=1;repeatGateScheduler=1;
% Set scheduling iteration count to 0
iteration=0;
% get Original Scenario Counts
n_orig_A=sum(FlightSchedule(:,2)==1);
n_orig_D=sum(FlightSchedule(:,2)==0);
n_orig=n_orig_A+n_orig_D;
while repeatArrSpacer==1 || repeatGateScheduler==1 || ...
        any(isnan(FlightSchedule(:,4)))
    iteration=iteration+1;  % increase interation count
    if repeatArrSpacer==1 || iteration==1
        % separate arrival flights on the runways
        [FlightSchedule repeatGateScheduler] =...
            SpaceArrivalFlights(FlightSchedule,newDir,newDate);
%         if repeatGateScheduler==1
%             disp('Repeat Gate Scheduler Code...')
%         end
        % Reset arrival repeater value to 0
        repeatArrSpacer=0;
    end
    if repeatGateScheduler==1 || iteration==1 || ...
            any(isnan(FlightSchedule(:,4)))
```

```
        % Schedule flights at the gates
        [FlightSchedule repeatArrSpacer GateInfo]=...
            GateScheduler2(FlightSchedule,newDir,newDate,30,300,iteration);
%         if repeatArrSpacer==1
%             disp('Repeat Arrival Spacer Code...')
%         end
        % Reset gate scheduler repeater value to 0
        repeatGateScheduler=0;
    end
    % Terminal Manager
    % Ensure that the terminal never is depleted or overcrowed. Return the
    % initial terminal size for each terminal. Do not run Terminal Manager
    % if there are NaN gates.
%     nanMask=isnan(FlightSchedule(:,4));
%     if ~any(nanMask)
%         [InitTerminalSize repeatFlagTM]=TerminalManager2(...
%             FlightSchedule,30,newDir,newDate);
%         if repeatFlagTM==1
%             repeatArrSpacer=1;
%             repeatGateScheduler=1;
%             repeatFlagTM=0;
%         end
%     end
end
% get Final Scenario Counts
n_fin_A=sum(FlightSchedule(:,2)==1);
n_fin_D=sum(FlightSchedule(:,2)==0);
n_fin=n_fin_A+n_fin_D;
FlightsRemoved=n_orig-n_fin;
%% Write the Flight schedule to a SOSS scenario file
% Create fields from the flight schedule
FlightID=FlightSchedule(:,1);
Category=FlightSchedule(:,2);
WeightClass=FlightSchedule(:,3);
Gate=FlightSchedule(:,4);
Spot=FlightSchedule(:,5);
Runway=FlightSchedule(:,6);
InTime=FlightSchedule(:,7);
OutTime=FlightSchedule(:,8);
OnTime=FlightSchedule(:,9);
OffTime=FlightSchedule(:,10);
SpotTime=FlightSchedule(:,11);
Spot_ATG=FlightSchedule(:,12);
% Separate Arrivals and departures

% Arrival Flights
FlightID_a=FlightID(Category==1);
WeightClass_a=WeightClass(Category==1);
Spot_a=Spot(Category==1);
Runway_a=Runway(Category==1);
ActivationTime_a=OnTime(Category==1);
for i=1:length(FlightID_a)
    [ArrExitNode(i,:) tempDepNode]=TemporaryExitNode(Runway_a(i),1,...
        WeightClass_a(i));
end
% Departure Flights
FlightID_d=FlightID(Category==0);
```

```
WeightClass_d=WeightClass(Category==0);
Spot_d=Spot(Category==0);
Runway_d=Runway(Category==0);
ActivationTime_d=SpotTime(Category==0);
%% Create Scenario Names
ATGScenarioName=strcat('ATG_Scenario_Type3_',sprintf('%d',...
    length(FlightID_d)),'_',sprintf('%d',length(FlightID_a)),...
    '_',DepLoading,'_',ArrLoading,'_',newDate,'.list_data');
SOSSScenarioName=strcat('SOSS_Scenario_Type3_',sprintf('%d',...
    length(FlightID_d)),'_',sprintf('%d',length(FlightID_a)),...
    '_',DepLoading,'_',ArrLoading,'_',newDate,'.txt');
%% Print the Scenario
% Output File for SOS Simulation
fid=fopen(SOSSScenarioName,'wt');
if exist('FlightID_a')
%      fprintf(fid,'%s %s %s %s %s %s\n',...
%          '#Model','Flight','Runway','Taxi_Exit_Node','Spot_Node','Time');
     fprintf(fid,'%d %d %d %d %d %f\n',...
            [WeightClass_a,FlightID_a,Runway_a,ArrExitNode,Spot_a,...
            ActivationTime_a]');
end
if exist('FlightID_d')
%     fprintf(fid,'%s %s %s %s %s\n',...
%         '#Model','Flight','Spot_Node','Runway','Time');
    fprintf(fid,'%d %d %d %d %f\n',...
            [WeightClass_d,FlightID_d,Spot_d,Runway_d,ActivationTime_d]');
end
fclose('all');
%% Create ATG Scenario from Flight Schedule
[fileout,numAircraft]=ATGScenarioBuilder(FlightSchedule,ATGScenarioName);
fprintf('%s %d\n','Original Scenario Count=',n_orig)
fprintf('%s %d\n','Final Scenario Count=',n_fin)
fprintf('%s %d\n','Flights Removed =',FlightsRemoved)
fprintf('%s %d\n','Total Arrival Aircraft Scheduled =',length(FlightID_a))
fprintf('%s %d\n','Total Departure Aircraft Scheduled =',length(FlightID_d))
fprintf('%s %d\n','Total Aircraft Scheduled =',numAircraft)
fprintf('%s %s\n','ATG Scenario File: ',fileout)
fprintf('%s %s\n','File Location:',cd)
%% Airport Usage Plots
AirportUsage(FlightSchedule,newDir,newDate,'Type3',SimTime/10)
```

APPENDIX F: HISTORICAL INPUT FILES FOR SCENARIO GENERATION

This section lists the files containing historical statistics data extracted from the Surface Operations Data Analysis and Adaptation (SODAA) tool. These files are read in as inputs by the Matlab scripts to generate the Spot and Runway Departure Advisor (SARDA) test scenarios.

WeightClassPercentages.txt

WeightClass	Percentage
Small	0
Large	81
Heavy	9
B757	10

SpotPercentages.txt

ATG Spot	Arrival Percentage	Departure Percentage
5	8	0
7	0	8
9	0	5
10	5	0
11	0	4
13	5	0
14	6	0
15	0	6
22	0	16
24	15	0
31	0	7
32	8	0
33	0	4
34	6	0
35	0	4
36	6	0
37	0	7
42	0	15
44	19	0
45	0	7
46	7	0
47	0	16
48	6	0
51	0	0
53	8	0

DepartureRunwayPercentages.txt

Origin	WeightClass	Runway17R	Runway13L	Runway18L
East	Small	85	0	15
East	Large	85	0	15
East	Heavy	85	0	15
East	B757	85	0	15
West	Small	50	0	50
West	Large	50	0	50
West	Heavy	50	0	50
West	B757	50	0	50

ArrivalRunwayPercentages.txt

Origin	WeightClass	Runway17C	Runway18R	Runway13R	Runway17L
East	Small	65	10	10	15
East	Large	45	15	15	25
East	Heavy	65	10	10	15
East	B757	65	10	10	15
West	Small	40	30	15	15
West	Large	40	30	15	15
West	Heavy	40	30	15	15
West	B757	40	30	15	15

SmallTypePercentages.txt

AircraftType	Count	Percentage
AC50	1	0
AC90	2	0
AEST	1	0
B99	20	2
BE10	1	0
BE33	1	0
BE35	9	1
BE36	9	1
BE55	5	1
BE58	4	0
BE76	1	0
BE90	26	3
BE95	1	0
BE99	17	2
BE9L	7	1
BE9T	1	0
C152	5	1
C172	49	6
C180	1	0
C182	7	1
C206	1	0
C208	249	30
C210	5	1
C340	3	0
C401	1	0
C402	36	4
C414	1	0
C421	5	1
C425	1	0
C441	1	0
C501	2	0
C525	8	1
C72R	1	0
CS	2	0
E120	208	25
HS25	2	0
MO20	2	0
MU2	17	2
P180	2	0
P28A	1	0
P46T	5	1
PA18	1	0
PA23	1	0
PA28	13	2
PA31	93	11
PA32	1	0
PA44	2	0
PA60	1	0
PARO	1	0
PAY1	1	0
PAY3	2	0
PC12	6	1

LargeTypePercentages.txt

AircraftType	Count	Percentage
A318	137	0
A319	994	2
A320	260	1
A321	3	0
B712	566	1
B733	719	2
B734	166	0
B735	583	1
B737	3751	8
B739	43	0
CRJ7	3053	6
E135	3332	7
E145	7337	15
E170	712	1
MD82	15490	33
MD83	4898	10
MD88	428	1
MD90	159	0

HeavyTypePercentages.txt

AircraftType	Count	Percentage
A332	59	2
B744	298	12
B747	1	0
B762	59	2
B763	686	28
B767	1	0
B772	407	17
B777	1	0

B757TypePercentages.txt

AircraftType	Count	Percentage
B752	2630	90
B753	1	5
B757	4	5

DepartureFixPercentages18L.txt

DepartureFix	Percentage
AKUNA	0
ARDIA	0
BLECO	10
CEOLA	11
CLARE	0
DARTZ	0
FERRA	15
GRABE	0
JASPA	5
LOWGN	8
NELYN	12
NOBLY	0
PODDE	21
SLOTT	9
SOLDO	0
TRISS	0

DepartureFixPercentages17R.txt

DepartureFix	Percentage
AKUNA	20
ARDIA	0
BLECO	0
CEOLA	0
CLARE	20
DARTZ	0
GRABE	10
JASPA	0
LOWGN	0
NELYN	0
NOBLY	20
PODDE	0
SLOTT	0
SOLDO	15
TRISS	15

Callsigns.xls

ICAO	Airline	CallSign	Fleet														
AAL	American Airlines	American	B738	B737	B752	B757	B762	B763	B767	B772	B777	MD82	MD83				
COA	Continental Airlines	Continental	B733	B735	B737	B738	B739	B752	B753	B757	B762	B764	B767	B772	B777		
DAL	Delta Airlines	Delta	B737	B738	B752	B757	B763	B764	B767	B772	B777	MD88	MD90				
EGF	American Eagle Airlines	Eagle flight	CRJ7	E135	E140	E145											
FFT	Frontier Airlines	Frontier flight	A318	A319	A320	E190											
MEP	Midwest Airlines	Midex	A319	E190	E170												
TRS	AirTran Airways	Citrus	B712	B737													
UAL	United Airlines	United	A319	A320	B744	B747	B752	B757	B763	B767	B772	B777					
USA	US Airways	Us air	A319	A320	A321	A332	A333	A358	A359	B733	B734	B737	B752	B757	B762	B767	E190

Runway17RDestinations.txt

Departure Meter Fix	Destination Airport	Count	%
AKUNA	STL	80	12
AKUNA	SGF	76	11
AKUNA	XNA	72	11
AKUNA	MKE	50	7
AKUNA	FSM	45	7
AKUNA	LGA	39	6
AKUNA	IND	30	4
AKUNA	GRR	21	3
AKUNA	BOS	19	3
AKUNA	FWA	17	3
AKUNA	MSN	17	3
AKUNA	PIA	16	2
AKUNA	EWR	11	2
AKUNA	MLI	11	2
ARDIA	HOU	28	85
ARDIA	IAH	2	6
CLARE	BTR	88	9
CLARE	JAN	76	8
CLARE	MIA	72	8
CLARE	PNS	63	7
CLARE	VPS	62	7
CLARE	FLL	59	6
CLARE	TPA	59	6
CLARE	MSY	52	6
CLARE	MCO	43	5
CLARE	TYR	42	5
CLARE	MOB	41	4
CLARE	GPT	35	4
CLARE	GGG	27	3
CLARE	JAX	24	3
CLARE	LFT	23	2
CLARE	AEX	22	2
CLARE	PBI	18	2
CLARE	RSW	17	2
DARTZ	IAH	131	74
GRABE	ORD	14	6
GRABE	CID	6	3
GRABE	BLE	4	2
GRABE	TUL	3	1
JASPA	AUS	4	7
JASPA	JAS	55	90
JASPA	MFE	1	2
NOBLY	CVG	80	11
NOBLY	LIT	78	11
NOBLY	DTW	72	10
NOBLY	CLE	55	8
NOBLY	EWR	44	6
NOBLY	SDF	40	6
NOBLY	CMH	38	5
NOBLY	LGA	35	5
NOBLY	BOS	28	4
NOBLY	IND	25	4
NOBLY	PHL	20	3
NOBLY	DAY	19	3
NOBLY	ORD	12	2
SOLDO	CLT	36	3
SOLDO	SHV	32	3
SOLDO	ATL	22	2
SOLDO	MLU	22	2
SOLDO	ELD	10	1
SOLDO	MEM	10	1
SOLDO	LGA	9	1
SOLDO	PHL	8	1
SOLDO	HSV	7	1
SOLDO	RDU	6	1
TRISS	PHL	77	9
TRISS	PIT	59	7
TRISS	BNA	57	7
TRISS	IAD	51	6
TRISS	BWI	46	6
TRISS	TYS	43	5
TRISS	EWR	36	4
TRISS	GSO	29	4
TRISS	TXK	28	3
TRISS	CLT	21	3
TRISS	ORF	21	3
TRISS	ATL	20	2
TRISS	LEX	20	2
TRISS	RIC	20	2
TRISS	JFK	19	2
TRISS	BOS	16	2
TRISS	RDU	16	2
TRISS	LGA	13	2
TRISS	BDL	10	1
TRISS	SDF	10	1

Runway18LDestinations.txt

Departure Meter Fix	Destination Airport	Count	%
AKUNA	SGF	12	19
AKUNA	XNA	9	14
AKUNA	FSM	7	11
AKUNA	STL	6	10
AKUNA	MKE	5	8
AKUNA	PIA	3	5
AKUNA	EGLL	2	3
AKUNA	GRA	2	3
AKUNA	GRR	2	3
AKUNA	IND	2	3
AKUNA	LGA	2	3
AKUNA	SDF	2	3
ARDIA	HOU	39	85
ARDIA	RAR	3	7
BLECO	BLE	317	85
BLECO	MSP	15	4
BLECO	MCI	7	2
BLECO	DSM	6	2
BLECO	DEN	4	1
BLECO	ICT	4	1
BLECO	OKC	4	1
BLECO	OMA	3	1
BLECO	ORD	2	1
BLECO	SEA	2	1
CEOLA	LAX	96	23
CEOLA	LAS	72	17
CEOLA	ABQ	64	16
CEOLA	SJC	41	10
CEOLA	SNA	0	0
CEOLA	DEN	10	2
CEOLA	SAN	10	2
CEOLA	BUR	9	2
CEOLA	PSP	9	2
CEOLA	SBA	8	2
CEOLA	ONT	7	2
CEOLA	SFO	5	1
CEOLA	OAK	4	1
CEOLA	SEA	4	1
CEOLA	FAT	3	1
DARTZ	IAH	11	11
DARTZ	MCO	1	1
DARTZ	RDA	1	1
FERRA	DEN	77	14
FERRA	AMA	73	13
FERRA	SLC	73	13
FERRA	SEA	68	12
FERRA	LAW	62	11
FERRA	SPS	57	10
FERRA	COS	39	7
FERRA	PDX	31	5
FERRA	GJT	21	4
FERRA	SFO	14	2
FERRA	SMF	11	2
FERRA	MTJ	5	1
GRABE	GRA	53	69
GRABE	BLE	8	10
GRABE	ORD	3	4
GRABE	TUL	3	4
GRABE	SGF	2	3
GRABE	XNA	2	3
GRABE	MLI	1	1
GRABE	MSN	1	1
GRABE	MSP	1	1
GRABE	PIA	1	1
GRABE	TOL	1	1
JASPA	JAS	160	82
JASPA	SAT	14	7
JASPA	AUS	8	4
JASPA	CLL	7	4
JASPA	CRP	2	1
LOWGN	DEN	123	43
LOWGN	OMA	30	10
LOWGN	BLE	25	9
LOWGN	SEA	12	4
LOWGN	MSP	11	4
LOWGN	COS	8	3
LOWGN	PDX	5	2
LOWGN	ORD	4	1
LOWGN	EGE	3	1
LOWGN	SLC	2	1
NELYN	GRK	99	22
NELYN	CRP	63	14
NELYN	ACT	50	11
NELYN	LRD	41	9
NELYN	MFE	27	6

NELYN	CLL	17	4
NELYN	JAS	5	1
PODDE	ABI	34	4
PODDE	SJT	23	3
PODDE	LAX	15	2
PODDE	PHX	14	2
PODDE	SAN	7	1
PODDE	ELP	6	1
PODDE	TUS	6	1
PODDE	SFO	5	1
PODDE	SNA	5	1
PODDE	MAF	4	1
PODDE	ONT	4	1
SLOTT	LBB	91	27
SLOTT	SFO	67	20
SLOTT	LAS	40	12
SLOTT	SMF	29	9
SLOTT	OAK	22	6
SLOTT	RNO	22	6
SLOTT	SJC	21	6
SLOTT	LAX	4	1
SLOTT	SEA	4	1
SLOTT	SLC	4	1
SLOTT	ABQ	3	1
SLOTT	GJT	3	1
SLOTT	AMA	2	1
SLOTT	DEN	2	1
SLOTT	PDX	2	1

APPENDIX G: ATG SCENARIO FILES FOR APRIL 2010 SIMULATIONS

This section lists the actual scenario files used during the April 2010 data collection runs. Four scenario files were generated for the test, consisting of two Normal and two High traffic characteristics. For each scenario file, three other 'alias' files were created by substituting only the aircraft call signs with ones that looked similar; all other aspects of the aircraft characteristics stayed the same. The idea was to present test subjects with more perceived variation in traffic. All other files spawned from these four profiles.

The Airspace Traffic Generator (ATG) scenario files are generated using a text file format and various tabbed fields (column headers). However, aircraft are defined according to each row in the file. The column headers are defined slightly differently depending upon different starting conditions—airborne or on the airport surface. The definitions for both types of starting points are defined below. (NOTE: The single text line has been broken up into two lines here for legibility.)

Flights Activated En Route or Airborne

Rules: This will be Instrument Flight Rules (IFR) for all flights.

Status: Airborne (en route) activated aircraft are assigned status RTE (route), typically for arrivals.

Call Sign: The flight identifier for the scenario.

Aircraft Type: Identifier used to retrieve the aircraft performance data in ATG. The file, '*aircraft_types_database*' is where this data is stored.

Speed: The flight's airspeed upon activation.

Altitude: The assigned altitude for the flight, either upon activation (RTE), or after airborne (GRD).

Start Time: The time at which the flight will appear on the ATG Ground Pilot Station (defined in seconds after start of scenario file and not ATG system start-up time).

Sector ID: Sector ownership of aircraft. This can be used to force automation, or determine default pseudo-pilot ownership of aircraft during initialization. A valid sector identification (ID) must be present in the following files before it will be accepted by ATG: *sector_names* and *ground_sectors*

Initial Point: The starting location for the flight when it enters the system. This can be a gate, spot, intersection on the surface of the airport, or any airborne position specified by a heading and radial distance from some point (usually a runway).

Destination Airport: The airport assigned to the flight for arrival.

Runway: The runway assigned to the flight for either departure or arrival.

Flight Plan: The route assigned to the flight that specifies how it will reach its destination.

Gate/Spot: Self explanatory.

Beacon: A four-digit unique transponder code for the flight. This can be left blank.

Flights Activated on the Surface

Rules: This will be Instrument Flight Rules (IFR) for all flights.

Status: Aircraft activated on the ground is assigned GRD**,** typically for departures.

Call Sign: The flight identifier for the scenario.

Aircraft Type: Identifier used to retrieve the aircraft performance data in ATG. The file '*aircraft_types_database*' is where this data is stored.

Speed: The flight's filed airspeed after it becomes airborne.

Altitude: The flight's filed altitude after becoming airborne.

Start Time: The time at which the flight will appear on the ATG Ground Pilot Station (defined in seconds after start of scenario file and not ATG system start-up time).

Sector ID: Sector ownership of aircraft. This can be used to force automation, or determine default pseudo-pilot ownership of aircraft during initialization. A valid sector ID must be present in the following files before it will be accepted by ATG: *sector_names* and *ground_sectors*

Initial Point: The starting location for the flight when it enters the system. This can be a gate, spot, intersection on the surface of the airport, or any airborne position specified by a heading and radial distance from some point (usually a runway).

Destination Airport: The airport assigned to the flight for arrival.

Runway: The runway assigned to the flight for either departure or arrival.

Origin Airport: The airport of origin for the flight (DFW for departures).

Flight Plan: The route assigned to the flight that specifies how it will reach its destination.

Orientation: The initial heading for any flight activated on the surface of the airport.

Gate/Spot: Self explanatory.

Beacon: A four-digit unique transponder code for the flight. This can be left blank.

Normal 1: ATG Scenario file for the 'Normal 1' run, consisting of 40 Arrivals, 40 Departures – **AIRBORNE** traffic.

Row 1:
Rules, Status, Call Sign, Aircraft Type, Aircraft Speed, Altitude, Start Time, Sector ID, Init_point

Row 2:
Airport, Runway, Flight Plan, Gate/Spot, Beacon

IFR	RTE	USA5596	B752	180	30	P82	arr17C7	DFW17C355010
	DFW	17C	DFW17C	gateE18/spot48				
IFR	RTE	DAL6526	MD80	180	30	P123	arr17C7	DFW17C355010
	DFW	17C	DFW17C	gateE11/spot46				
IFR	RTE	FFT826	A319	180	30	P354	arr17C7	DFW17C355010
	DFW	17C	DFW17C	gateE20/spot48				
IFR	RTE	AAL7318	B752	180	30	P544	arr17C4	DFW17C355010
	DFW	17C	DFW17C	gateC20/spot34				
IFR	RTE	AAL69	B763	180	30	P755	arr17C4	DFW17C355010
	DFW	17C	DFW17C	gateC21/spot34				
IFR	RTE	AAL8865	B738	180	30	P996	arr17C3	DFW17C355010
	DFW	17C	DFW17C	gateA9/spot5				
IFR	RTE	AAL868	MD80	180	30	P1076	arr17C3	DFW17C355010
	DFW	17C	DFW17C	gateA17/spot10				
IFR	RTE	EGF4885	E145	180	30	P1265	arr17C3	DFW17C355010
	DFW	17C	DFW17C	gateA35/spot24				
IFR	RTE	EGF4425	E145	180	30	P1441	arr17C4	DFW17C355010
	DFW	17C	DFW17C	gateC32/spot44				
IFR	RTE	AAL3787	MD82	180	30	P1646	arr17C3	DFW17C355010
	DFW	17C	DFW17C	gateA36/spot24				
IFR	RTE	AAL593	MD82	180	30	P1881	arr17C4	DFW17C355010
	DFW	17C	DFW17C	gateC24/spot34				
IFR	RTE	AAL736	MD82	180	30	P2044	arr17C3	DFW17C355010
	DFW	17C	DFW17C	gateA37/spot24				
IFR	RTE	DAL13	B763	180	30	P2236	arr17C7	DFW17C355010
	DFW	17C	DFW17C	gateE11/spot46				
IFR	RTE	AAL991	MD80	180	30	P2393	arr17C3	DFW17C355010
	DFW	17C	DFW17C	gateA16/spot10				
IFR	RTE	UAL458	A319	180	30	P2559	arr17C7	DFW17C355010
	DFW	17C	DFW17C	gateE18/spot48				
IFR	RTE	AAL976	B738	180	30	P97	arr18R2	DFW18R355010
	DFW	18R	DFW18R	gateA16/spot10				
IFR	RTE	EGF4446	E145	180	30	P268	arr18R1	DFW18R355010
	DFW	18R	DFW18R	gateA9/spot5				
IFR	RTE	AAL42	B763	180	30	P736	arr18R2	DFW18R355010
	DFW	18R	DFW18R	gateC27/spot36				
IFR	RTE	AAL7985	B738	180	30	P1250	arr18R2	DFW18R355010
	DFW	18R	DFW18R	gateC33/spot44				
IFR	RTE	EGF4159	E135	180	30	P1464	arr18R2	DFW18R355010
	DFW	18R	DFW18R	gateC35/spot44				
IFR	RTE	AAL9438	MD82	180	30	P1901	arr18R2	DFW18R355010
	DFW	18R	DFW18R	gateC32/spot44				
IFR	RTE	EGF4994	E135	180	30	P2357	arr18R2	DFW18R355010
	DFW	18R	DFW18R	gateC33/spot44				
IFR	RTE	DAL778	MD80	180	30	P2536	arr18R2	DFW18R355010

	DFW	18R	DFW18R		gateE33/spot53				
IFR	RTE	AAL617		B738	180	30	P174	arr13R2	DFW13R310010
	DFW	13R	DFW13R		gateA34/spot24				
IFR	RTE	EGF4637		E145	180	30	P313	arr13R2	DFW13R31001
0	DFW	13R	DFW13R		gateA23/spot14				
IFR	RTE	AAL187		MD83	180	30	P585	arr13R2	DFW13R310010
	DFW	13R	DFW13R		gateC26/spot36				
IFR	RTE	AAL8396		MD83	180	30	P979	arr13R2	DFW13R310010
	DFW	13R	DFW13R		gateC31/spot44				
IFR	RTE	EGF4394		E145	180	30	P1232	arr13R2	DFW13R310010
	DFW	13R	DFW13R		gateA24/spot14				
IFR	RTE	DAL969		MD80	180	30	P1529	arr13R2	DFW13R310010
	DFW	13R	DFW13R		gateE18/spot48				
IFR	RTE	COA85		B762	180	30	P1872	arr13R2	DFW13R310010
	DFW	13R	DFW13R		gateE13/spot46				
IFR	RTE	DAL1665		MD80	180	30	P2083	arr13R2	DFW13R310010
	DFW	13R	DFW13R		gateE32/spot53				
IFR	RTE	AAL1867		MD82	180	30	P2397	arr13R2	DFW13R310010
	DFW	13R	DFW13R		gateA39/spot24				
IFR	RTE	DAL6925		MD80	180	30	P2571	arr13R2	DFW13R310010
	DFW	13R	DFW13R		gateE34/spot53				
IFR	RTE	AAL727		B738	180	30	P92	arr17L1	DFW17L355010
	DFW	17L	DFW17L		gateC31/spot44				
IFR	RTE	AAL413		B752	180	30	P318	arr17L2	DFW17L355010
	DFW	17L	DFW17L		gateA21/spot13				
IFR	RTE	EGF4841		E135	180	30	P871	arr17L2	DFW17L355010
	DFW	17L	DFW17L		gateA10/spot5				
IFR	RTE	AAL937		B752	180	30	P1406	arr17L1	DFW17L355010
	DFW	17L	DFW17L		gateC22/spot34				
IFR	RTE	AAL3497		B738	180	30	P1891	arr17L1	DFW17L355010
	DFW	17L	DFW17L		gateC25/spot34				
IFR	RTE	AAL646		MD80	180	30	P2227	arr17L2	DFW17L355010
	DFW	17L	DFW17L		gateA38/spot24				
IFR	RTE	AAL2871		MD82	180	30	P2554	arr17L1	DFW17L355010
	DFW	17L	DFW17L		gateC27/spot36				

Normal 1: ATG Scenario file for the 'Normal 1' run, consisting of 40 Arrivals, 40 Departures – **SURFACE** traffic.

Row 1:
Rules, Status, Call Sign, Aircraft Type, Aircraft Speed, Altitude, Start Time, Sector ID, Init_point, Destination

Row 2:
Runway, Origin, Flight Plan, Orient, Gate/Spot, Beacon

IFR	GRD	AAL3617	MD82	250	150	P90	DgateC31	gateC31	LGA
	17R	DFW	DFW.SOLDO#.SOLDO..LGA			330	gateC31/spot37		
IFR	GRD	DAL427	MD80	250	150	P138	DgateE8	gateE8	SDF
	17R	DFW	DFW.TRISS#.TXK..SDF			180	gateE8/spot42		
IFR	GRD	FFT849	A319	250	150	P139	DgateE38	gateE38	SHV
	17R	DFW	DFW.SOLDO#.SOLDO..SHV			350	gateE38/spot47		
IFR	GRD	AAL453	B752	250	150	P146	DgateC27	gateC27	ATL
	17R	DFW	DFW.TRISS#.TXK..ATL 280			gateC27/spot37			
IFR	GRD	AAL941	MD82	250	150	P153	DgateA9	gateA9	MCO
	17R	DFW	DFW.CLARE#.EIC..MCO			170	gateA9/spot7		
IFR	GRD	EGF4737	E135	250	150	P218	DgateC33	gateC33	STL
	17R	DFW	DFW.AKUNA#.MLC..STL			350	gateC33/spot42		
IFR	GRD	DAL9526	MD80	250	150	P222	DgateE16	gateE16	TXK
	17R	DFW	DFW.TRISS#.TXK..TXK250			gateE16/spot47			
IFR	GRD	DAL761	MD80	250	150	P254	DgateE9	gateE9	BLE
	18L	DFW	DFW.BLECO#.IRW..BLE			220	gateE9/spot45		
IFR	GRD	DAL914	MD80	250	150	P340	DgateE33	gateE33	JAN
	17R	DFW	DFW.CLARE#.EIC..JAN			300	gateE33/spot47		
IFR	GRD	DAL136	MD80	250	150	P357	DgateE15	gateE15	ORD
	17R	DFW	DFW.GRABE#.EAKER..ORD			250	gateE15/spot45		
IFR	GRD	DAL349	MD80	250	150	P474	DgateE21	gateE21	DTW
	17R	DFW	DFW.NOBLY#.LIT..DTW			300	gateE21/spot47		
IFR	GRD	EGF4845	E145	250	150	P577	DgateA16	gateA16	SHV
	17R	DFW	DFW.SOLDO#.SOLDO..SHV			190	gateA16/spot9		
IFR	GRD	DAL9935	MD80	250	150	P583	DgateE31	gateE31	CVG
	17R	DFW	DFW.NOBLY#.LIT..CVG			300	gateE31/spot47		
IFR	GRD	AAL21	B772	250	150	P679	DgateC11	gateC11	SEA
	18L	DFW	DFW.LOWGN#.LOWGN..SEA			200	gateC11/spot31		
IFR	GRD	AAL6671	MD83	250	150	P697	DgateA15	gateA15	CID
	17R	DFW	DFW.GRABE#.EAKER..CID			190	gateA15/spot7		
IFR	GRD	AAL1627	B752	250	150	P815	DgateA17	gateA17	COS
	18L	DFW	DFW.FERRA#.PNH..COS			220	gateA17/spot9		
IFR	GRD	AAL547	MD82	250	150	P955	DgateC31	gateC31	SGF
	17R	DFW	DFW.AKUNA#.MLC..SGF			330	gateC31/spot37		
IFR	GRD	AAL894	MD83	250	150	P962	DgateC22	gateC22	LAW
	18L	DFW	DFW.FERRA#.PNH..LAW			270	gateC22/spot35		
IFR	GRD	EGF4361	E145	250	150	P989	DgateA22	gateA22	BTR
	17R	DFW	DFW.CLARE#.EIC..BTR			270	gateA22/spot15		
IFR	GRD	AAL465	MD82	250	150	P1002	DgateC12	gateC12	GPT
	17R	DFW	DFW.CLARE#.EIC..GPT			200	gateC12/spot31		
IFR	GRD	AAL3882	B737	250	150	P1002	DgateA33	gateA33	MSY
	17R	DFW	DFW.CLARE#.EIC..MSY			310	gateA33/spot22		
IFR	GRD	EGF4473	E135	250	150	P1046	DgateA18	gateA18	TYR
	17R	DFW	DFW.CLARE#.EIC..TYR			220	gateA18/spot9		

IFR	GRD	DAL476	MD80	250	150	P1051	DgateE10	gateE10	FLL
	17R	DFW	DFW.CLARE#.EIC..FLL	200	gateE10/spot45				
IFR	GRD	AAL4619	MD82	250	150	P1116	DgateA16	gateA16	DAY
	17R	DFW	DFW.NOBLY#.LIT..DAY	190	gateA16/spot9				
IFR	GRD	AAL278	MD82	250	150	P1133	DgateC24	gateC24	CLT
	17R	DFW	DFW.SOLDO#.SOLDO..CLT	270	gateC24/spot35				
IFR	GRD	AAL4139	MD82	250	150	P1171	DgateA37	gateA37	TYR
	17R	DFW	DFW.CLARE#.EIC..TYR	350	gateA37/spot22				
IFR	GRD	DAL3312	MD80	250	150	P1177	DgateE11	gateE11	ORD
	17R	DFW	DFW.GRABE#.EAKER..ORD	220	gateE11/spot45				
IFR	GRD	DAL345	MD80	250	150	P1236	DgateE17	gateE17	CMH
	17R	DFW	DFW.NOBLY#.LIT..CMH	270	gateE17/spot47				
IFR	GRD	EGF4452	E145	250	150	P1244	DgateA9	gateA9	LAX
		18L	DFW	DFW.PODDE#.MQP..LAX	170	gateA9/spot7			
IFR	GRD	AAL533	B738	250	150	P1355	DgateA24	gateA24	CLT
	17R	DFW	DFW.SOLDO#.SOLDO..CLT	290	gateA24/spot15				
IFR	GRD	EGF4696	E145	250	150	P1385	DgateC14	gateC14	CLT
	17R	DFW	DFW.SOLDO#.SOLDO..CLT	200	gateC14/spot31				
IFR	GRD	USA629	B752	250	150	P1500	DgateE18	gateE18	GPT
	17R	DFW	DFW.CLARE#.EIC..GPT	270	gateE18/spot47				
IFR	GRD	AAL397	B738	250	150	P1574	DgateA10	gateA10	XNA
	17R	DFW	DFW.AKUNA#.MLC..XNA	170	gateA10/spot7				
IFR	GRD	AAL8658	B738	250	150	P1663	DgateA20	gateA20	LIT
	17R	DFW	DFW.NOBLY#.LIT..LIT	230	gateA20/spot11				
IFR	GRD	EGF4339	E145	250	150	P1764	DgateC15	gateC15	ORF
	17R	DFW	DFW.TRISS#.TXK..ORF	200	gateC15/spot31				
IFR	GRD	AAL7463	B752	250	150	P1950	DgateC27	gateC27	ORD
	17R	DFW	DFW.GRABE#.EAKER..ORD	280	gateC27/spot37				
IFR	GRD	AAL6316	MD80	250	150	P2139	DgateA23	gateA23	STL
	17R	DFW	DFW.AKUNA#.MLC..STL	290	gateA23/spot15				
IFR	GRD	AAL257	MD82	250	150	P2196	DgateC32	gateC32	SGF
	17R	DFW	DFW.AKUNA#.MLC..SGF	10	gateC32/spot42				
IFR	GRD	EGF4848	E145	250	150	P2541	DgateC33	gateC33	SEA
	18L	DFW	DFW.FERRA#.PNH..SEA	350	gateC33/spot42				
IFR	GRD	MEP4444	E170	250	150	P2615	DgateE18	gateE18	SJT
	18L	DFW	DFW.PODDE#.MQP..SJT	270	gateE18/spot47				

Normal 2: ATG Scenario file for the 'Normal 2' run, consisting of 40 Arrivals, 40 Departures – **AIRBORNE** traffic

Row 1:
Rules, Status, Call Sign, Aircraft Type, Aircraft Speed, Altitude, Start Time, Sector ID, Init_point

Row 2:
Airport, Runway, Flight Plan, Gate/Spot, Beacon

IFR	RTE	AAL274	MD82	180	30	P33	arr17C4	DFW17C355010
	DFW	17C	DFW17C	gateC31/spot44				
IFR	RTE	AAL7657	MD80	180	30	P114	arr17C3	DFW17C355010
	DFW	17C	DFW17C	gateA9/spot5				
IFR	RTE	UAL866	B752	180	30	P389	arr17C7	DFW17C355010
	DFW	17C	DFW17C	gateE18/spot48				
IFR	RTE	EGF4828	E145	180	30	P448	arr17C3	DFW17C355010
	DFW	17C	DFW17C	gateA23/spot14				
IFR	RTE	AAL826	MD82	180	30	P687	arr17C4	DFW17C355010
	DFW	17C	DFW17C	gateC26/spot36				
IFR	RTE	AAL1737	B752	180	30	P819	arr17C3	DFW17C355010
	DFW	17C	DFW17C	gateA26/spot14				
IFR	RTE	AAL529	MD80	180	30	P987	arr17C3	DFW17C355010
	DFW	17C	DFW17C	gateA28/spot14				
IFR	RTE	AAL169	B752	180	30	P1146	arr17C3	DFW17C355010
	DFW	17C	DFW17C	gateA29/spot14				
IFR	RTE	AAL3254	MD82	180	30	P1279	arr17C4	DFW17C355010
	DFW	17C	DFW17C	gateC11/spot32				
IFR	RTE	AAL36	B763	180	30	P1534	arr17C3	DFW17C355010
	DFW	17C	DFW17C	gateA16/spot10				
IFR	RTE	AAL6327	MD83	180	30	P1589	arr17C3	DFW17C355010
	DFW	17C	DFW17C	gateA21/spot13				
IFR	RTE	DAL848	MD80	180	30	P1801	arr17C7	DFW17C355010
	DFW	17C	DFW17C	gateE33/spot53				
IFR	RTE	AAL4186	MD80	180	30	P1915	arr17C4	DFW17C355010
	DFW	17C	DFW17C	gateC11/spot32				
IFR	RTE	EGF4637	CRJ7	180	30	P2058	arr17C3	DFW17C355010
	DFW	17C	DFW17C	gateA38/spot24				
IFR	RTE	DAL1494	MD80	180	30	P2266	arr17C7	DFW17C355010
	DFW	17C	DFW17C	gateE11/spot46				
IFR	RTE	DAL688	MD80	180	30	P2390	arr17C7	DFW17C355010
	DFW	17C	DFW17C	gateE36/spot53				
IFR	RTE	AAL77	B772	180	30	P2640	arr17C4	DFW17C355010
	DFW	17C	DFW17C	gateC22/spot34				
IFR	RTE	AAL5982	MD82	180	30	P58	arr18R2	DFW18R355010
	DFW	18R	DFW18R	gateC32/spot44				
IFR	RTE	AAL515	MD82	180	30	P301	arr18R2	DFW18R355010
	DFW	18R	DFW18R	gateA25/spot14				
IFR	RTE	EGF4785	E145	180	30	P911	arr18R2	DFW18R355010
	DFW	18R	DFW18R	gateA34/spot24				
IFR	RTE	AAL979	MD82	180	30	P1083	arr18R2	DFW18R355010
	DFW	18R	DFW18R	gateA35/spot24				
IFR	RTE	AAL311	B757	180	30	P1681	arr18R2	DFW18R355010
	DFW	18R	DFW18R	gateC21/spot34				

IFR	RTE	AAL794	MD83	180	30	P2010	arr18R2	DFW18R355010	DFW	18R	DFW18R	gateA16/spot10
IFR	RTE	AAL5774	B752	180	30	P2303	arr18R2	DFW18R355010	DFW	18R	DFW18R	gateC12/spot32
IFR	RTE	AAL5257	B738	180	30	P2622	arr18R2	DFW18R355010	DFW	18R	DFW18R	gateA39/spot24
IFR	RTE	EGF4779	E145	180	30	P324	arr13R1	DFW13R310010	DFW	13R	DFW13R	gateA9/spot5
IFR	RTE	AAL416	MD82	180	30	P1069	arr13R2	DFW13R310010	DFW	13R	DFW13R	gateC31/spot44
IFR	RTE	AAL4453	MD80	180	30	P1490	arr13R2	DFW13R310010	DFW	13R	DFW13R	gateA37/spot24
IFR	RTE	AAL295	MD82	180	30	P2562	arr13R2	DFW13R310010	DFW	13R	DFW13R	gateC32/spot44
IFR	RTE	AAL164	MD83	180	30	P114	arr17L1	DFW17L355010	DFW	17L	DFW17L	gateC33/spot44
IFR	RTE	AAL8166	MD80	180	30	P195	arr17L2	DFW17L355010	DFW	17L	DFW17L	gateA24/spot14
IFR	RTE	DAL5926	MD80	180	30	P594	arr17L1	DFW17L355010	DFW	17L	DFW17L	gateE32/spot53
IFR	RTE	AAL684	MD82	180	30	P897	arr17L1	DFW17L355010	DFW	17L	DFW17L	gateC35/spot44
IFR	RTE	AAL682	MD82	180	30	P1062	arr17L1	DFW17L355010	DFW	17L	DFW17L	gateC20/spot34
IFR	RTE	EGF4277	E145	180	30	P1408	arr17L2	DFW17L355010	DFW	17L	DFW17L	gateA36/spot24
IFR	RTE	EGF4536	CRJ7	180	30	P1497	arr17L2	DFW17L355010	DFW	17L	DFW17L	gateA17/spot10
IFR	RTE	DAL6277	MD80	180	30	P1757	arr17L1	DFW17L355010	DFW	17L	DFW17L	gateE34/spot53
IFR	RTE	DAL8292	MD80	180	30	P2056	arr17L1	DFW17L355010	DFW	17L	DFW17L	gateE35/spot53
IFR	RTE	COA336	B738	180	30	P2459	arr17L1	DFW17L355010	DFW	17L	DFW17L	gateE18/spot48
IFR	RTE	DAL242	MD80	180	30	P2559	arr17L1	DFW17L355010	DFW	17L	DFW17L	gateE20/spot48

Normal 2: ATG Scenario file for the 'Normal 2' run, consisting of 40 Arrivals, 40 Departures – **SURFACE** traffic

Row 1:
Rules, Status, Call Sign, Aircraft Type, Aircraft Speed, Altitude, Start Time, Sector ID, Init_point, Destination

Row 2:
Runway, Origin, Flight Plan, Orient, Gate/Spot, Beacon

IFR	GRD	DAL758	MD80	250	150	P90	DgateE38	gateE38	DTW
	17R	DFW	DFW.NOBLY#.LIT..DTW			350	gateE38/spot47		
IFR	GRD	AAL2771	MD80	250	150	P130	DgateA33	gateA33	DTW
	17R	DFW	DFW.NOBLY#.LIT..DTW			310	gateA33/spot22		
IFR	GRD	EGF4181	E145	250	150	P160	DgateA9	gateA9	MSP
	18L	DFW	DFW.BLECO#.IRW..MSP			170	gateA9/spot7		
IFR	GRD	UAL841	A319	250	150	P194	DgateE16	gateE16	SJT
	18L	DFW	DFW.PODDE#.MQP..SJT			250	gateE16/spot47		
IFR	GRD	DAL1971	MD80	250	150	P247	DgateE9	gateE9	BLE
	17R	DFW	DFW.GRABE#.EAKER..BLE			220	gateE9/spot45		
IFR	GRD	AAL121	MD82	250	150	P267	DgateA10	gateA10	IND
	17R	DFW	DFW.NOBLY#.LIT..IND 170			gateA10/spot7			
IFR	GRD	DAL54	B763	250	150	P329	DgateE15	gateE15	TPA
	17R	DFW	DFW.CLARE#.EIC..TPA			250	gateE15/spot45		
IFR	GRD	EGF4838	E145	250	150	P379	DgateA11	gateA11	FSM
	17R	DFW	DFW.AKUNA#.MLC..FSM			180	gateA11/spot7		
IFR	GRD	EGF4325	E135	250	150	P390	DgateC17	gateC17	STL
	17R	DFW	DFW.AKUNA#.MLC..STL			230	gateC17/spot33		
IFR	GRD	AAL7321	B752	250	150	P457	DgateA20	gateA20	DEN
	18L	DFW	DFW.FERRA#.PNH..DEN			230	gateA20/spot11		
IFR	GRD	AAL455	MD82	250	150	P484	DgateA12	gateA12	BTR
	17R	DFW	DFW.CLARE#.EIC..BTR			190	gateA12/spot7		
IFR	GRD	AAL5897	B738	250	150	P528	DgateC11	gateC11	ATL
	17R	DFW	DFW.SOLDO#.SOLDO..ATL			200	gateC11/spot31		
IFR	GRD	AAL379	MD82	250	150	P550	DgateC19	gateC19	XNA
	17R	DFW	DFW.AKUNA#.MLC..XNA			220	gateC19/spot33		
IFR	GRD	AAL776	MD80	250	150	P576	DgateC33	gateC33	GRR
	17R	DFW	DFW.AKUNA#.MLC..GRR			350	gateC33/spot42		
IFR	GRD	DAL9612	MD80	250	150	P684	DgateE8	gateE8	PIT
	17R	DFW	DFW.TRISS#.TXK..PIT 180			gateE8/spot42			
IFR	GRD	AAL9252	MD82	250	150	P720	DgateC31	gateC31	FSM
	17R	DFW	DFW.AKUNA#.MLC..FSM			330	gateC31/spot37		
IFR	GRD	DAL958	MD80	250	150	P868	DgateE17	gateE17	PBI
	17R	DFW	DFW.CLARE#.EIC..PBI 270			gateE17/spot47			
IFR	GRD	UAL86	B772	250	150	P1021	DgateE10	gateE10	TPA
	17R	DFW	DFW.CLARE#.EIC..TPA			200	gateE10/spot45		
IFR	GRD	AAL377	MD82	250	150	P1023	DgateA34	gateA34	ORD
	17R	DFW	DFW.GRABE#.EAKER..ORD			330	gateA34/spot22		
IFR	GRD	EGF4674	CRJ7	250	150	P1090	DgateA9	gateA9	LAS
	18L	DFW	DFW.SLOTT#.TCC..LAS			170	gateA9/spot7		
IFR	GRD	DAL595	MD80	250	150	P1129	DgateE18	gateE18	TYS
	17R	DFW	DFW.TRISS#.TXK..TYS270			gateE18/spot47			

IFR	GRD	AAL518	MD82	250	150	P1169	DgateC12	gateC12	GPT
	17R	DFW	DFW.CLARE#.EIC..GPT			200	gateC12/spot31		
IFR	GRD	EGF4217	E145	250	150	P1206	DgateA22	gateA22	CID
	17R	DFW	DFW.GRABE#.EAKER..CID			270	gateA22/spot15		
IFR	GRD	AAL6786	MD82	250	150	P1277	DgateA13	gateA13	BLE
	18L	DFW	DFW.BLECO#.IRW..BLE			190	gateA13/spot7		
IFR	GRD	DAL75	B763	250	150	P1304	DgateE11	gateE11	LFT
	17R	DFW	DFW.CLARE#.EIC..LFT		220	gateE11/spot45			
IFR	GRD	EGF4671	E135	250	150	P1347	DgateC8	gateC8	GRR
	17R	DFW	DFW.AKUNA#.MLC..GRR			220	gateC8/spot22		
IFR	GRD	AAL7133	MD80	250	150	P1455	DgateC20	gateC20	PIT
	17R	DFW	DFW.TRISS#.TXK..PIT		270	gateC20/spot33			
IFR	GRD	AAL376	MD82	250	150	P1493	DgateC14	gateC14	STL
	17R	DFW	DFW.AKUNA#.MLC..STL			200	gateC14/spot31		
IFR	GRD	AAL7169	MD82	250	150	P1591	DgateC22	gateC22	BNA
	17R	DFW	DFW.TRISS#.TXK..BNA			270	gateC22/spot35		
IFR	GRD	AAL297	MD82	250	150	P1721	DgateC21	gateC21	JAN
	17R	DFW	DFW.CLARE#.EIC..JAN			270	gateC21/spot33		
IFR	GRD	EGF4775	E145	250	150	P1771	DgateA9	gateA9	FWA
	17R	DFW	DFW.AKUNA#.MLC..FWA			170	gateA9/spot7		
IFR	GRD	EGF4568	E145	250	150	P1903	DgateA21	gateA21	MIA
	17R	DFW	DFW.CLARE#.EIC..MIA		270	gateA21/spot11			
IFR	GRD	AAL8457	B752	250	150	P1963	DgateC11	gateC11	LIT
	17R	DFW	DFW.NOBLY#.LIT..LIT		200	gateC11/spot31			
IFR	GRD	AAL1561	MD82	250	150	P2027	DgateC32	gateC32	BOS
	17R	DFW	DFW.NOBLY#.LIT..BOS			10	gateC32/spot42		
IFR	GRD	AAL8784	MD80	250	150	P2196	DgateC27	gateC27	CRP
	18L	DFW	DFW.NELYN#.NELYN..CRP			280	gateC27/spot37		
IFR	GRD	EGF4469	E135	250	150	P2230	DgateC33	gateC33	LIT
	17R	DFW	DFW.NOBLY#.LIT..LIT		350	gateC33/spot42			
IFR	GRD	COA1751	B752	250	150	P2377	DgateE21	gateE21	LAX
	18L	DFW	DFW.CEOLA#.CNX..LAX			300	gateE21/spot47		
IFR	GRD	DAL233	B738	250	150	P2487	DgateE31	gateE31	PBI
	17R	DFW	DFW.CLARE#.EIC..PBI		300	gateE31/spot47			
IFR	GRD	AAL7997	MD80	250	150	P2530	DgateA16	gateA16	MAF
	18L	DFW	DFW.PODDE#.MQP..MAF			190	gateA16/spot9		
IFR	GRD	EGF4942	E145	250	150	P2600	DgateC35	gateC35	STL
	17R	DFW	DFW.AKUNA#.MLC..STL			350	gateC35/spot42		

Heavy 1: ATG Scenario file for the 'Heavy 1' run, consisting of 60 Arrivals, 64 Departures – **AIRBORNE** traffic.

Row 1:
Rules, Status, Call Sign, Aircraft Type, Aircraft Speed, Altitude, Start Time, Sector ID, Init_point

Row 2:
Airport, Runway, Flight Plan, Gate/Spot, Beacon

IFR	RTE	EGF4251	E145	180	30	P18	arr17C4	DFW17C355010
	DFW	17C	DFW17C	gateC31/spot44				
IFR	RTE	DAL616	MD80	180	30	P119	arr17C7	DFW17C355010
	DFW	17C	DFW17C	gateE11/spot46				
IFR	RTE	AAL53	B772	180	30	P263	arr17C3	DFW17C355010
	DFW	17C	DFW17C	gateA21/spot13				
IFR	RTE	AAL6542	MD82	180	30	P316	arr17C3	DFW17C355010
	DFW	17C	DFW17C	gateA9/spot5				
IFR	RTE	AAL587	MD80	180	30	P419	arr17C3	DFW17C355010
	DFW	17C	DFW17C	gateA10/spot5				
IFR	RTE	AAL265	B752	180	30	P560	arr17C3	DFW17C355010
	DFW	17C	DFW17C	gateA22/spot13				
IFR	RTE	DAL1665	MD80	180	30	P601	arr17C7	DFW17C355010
	DFW	17C	DFW17C	gateE38/spot53				
IFR	RTE	EGF4783	E145	180	30	P711	arr17C4	DFW17C355010
	DFW	17C	DFW17C	gateC20/spot34				
IFR	RTE	AAL281	MD83	180	30	P827	arr17C4	DFW17C355010
	DFW	17C	DFW17C	gateC27/spot36				
IFR	RTE	AAL96	B762	180	30	P922	arr17C3	DFW17C355010
	DFW	17C	DFW17C	gateA23/spot14				
IFR	RTE	AAL1892	B738	180	30	P1058	arr17C4	DFW17C355010
	DFW	17C	DFW17C	gateC28/spot36				
IFR	RTE	AAL2244	MD82	180	30	P1117	arr17C3	DFW17C355010
	DFW	17C	DFW17C	gateA16/spot10				
IFR	RTE	AAL759	MD80	180	30	P1213	arr17C3	DFW17C355010
	DFW	17C	DFW17C	gateA13/spot5				
IFR	RTE	AAL6745	MD83	180	30	P1331	arr17C3	DFW17C355010
	DFW	17C	DFW17C	gateA14/spot5				
IFR	RTE	AAL5773	B752	180	30	P1463	arr17C3	DFW17C355010
	DFW	17C	DFW17C	gateA24/spot14				
IFR	RTE	AAL819	B757	180	30	P1774	arr17C3	DFW17C355010
	DFW	17C	DFW17C	gateA25/spot14				
IFR	RTE	USA987	B752	180	30	P1669	arr17C7	DFW17C355010
	DFW	17C	DFW17C	gateE11/spot46				
IFR	RTE	DAL5419	MD80	180	30	P1710	arr17C7	DFW17C355010
	DFW	17C	DFW17C	gateE13/spot46				
IFR	RTE	AAL17	B772	180	30	P1875	arr17C4	DFW17C355010
	DFW	17C	DFW17C	gateC26/spot36				
IFR	RTE	UAL45	B763	180	30	P1972	arr17C7	DFW17C355010
	DFW	17C	DFW17C	gateE14/spot46				
IFR	RTE	AAL514	MD80	180	30	P2011	arr17C4	DFW17C355010
	DFW	17C	DFW17C	gateC33/spot44				
IFR	RTE	AAL16	B762	180	30	P2126	arr17C4	DFW17C355010
	DFW	17C	DFW17C	gateC27/spot36				

IFR	RTE	EGF4737	CRJ7	180	30	P2195	arr17C4	DFW17C355010
	DFW	17C	DFW17C	gateC11/spot32				
IFR	RTE	UAL9857	B752	180	30	P2353	arr17C7	DFW17C355010
	DFW	17C	DFW17C	gateE15/spot46				
IFR	RTE	DAL9286	MD80	180	30	P2408	arr17C7	DFW17C355010
	DFW	17C	DFW17C	gateE33/spot53				
IFR	RTE	DAL981	MD80	180	30	P2505	arr17C7	DFW17C355010
	DFW	17C	DFW17C	gateE16/spot46				
IFR	RTE	EGF4469	E145	180	30	P2598	arr17C3	DFW17C355010
	DFW	17C	DFW17C	gateA10/spot5				
IFR	RTE	EGF4794	CRJ7	180	30	P139	arr18R2	DFW18R355010
	DFW	18R	DFW18R	gateC32/spot44				
IFR	RTE	EGF4982	E145	180	30	P475	arr18R1	DFW18R355010
	DFW	18R	DFW18R	gateA11/spot5				
IFR	RTE	AAL7344	B738	180	30	P966	arr18R1	DFW18R355010
	DFW	18R	DFW18R	gateA12/spot5				
IFR	RTE	AAL719	MD82	180	30	P1497	arr18R2	DFW18R355010
	DFW	18R	DFW18R	gateC32/spot44				
IFR	RTE	EGF4885	E145	180	30	P1624	arr18R2	DFW18R355010
	DFW	18R	DFW18R	gateA22/spot13				
IFR	RTE	AAL766	MD83	180	30	P2247	arr18R1	DFW18R355010
	DFW	18R	DFW18R	gateA9/spot5				
IFR	RTE	EGF4585	E145	180	30	P2564	arr18R2	DFW18R355010
	DFW	18R	DFW18R	gateC37/spot44				
IFR	RTE	DAL6758	MD80	180	30	P36	arr13R2	DFW13R310010
	DFW	13R	DFW13R	gateE13/spot46				
IFR	RTE	EGF4919	CRJ7	180	30	P203	arr13R2	DFW13R310010
	DFW	13R	DFW13R	gateC33/spot44				
IFR	RTE	AAL2874	MD82	180	30	P368	arr13R2	DFW13R310010
	DFW	13R	DFW13R	gateC26/spot36				
IFR	RTE	AAL678	MD82	180	30	P633	arr13R2	DFW13R310010
	DFW	13R	DFW13R	gateA21/spot13				
IFR	RTE	EGF4543	E145	180	30	P749	arr13R2	DFW13R310010
	DFW	13R	DFW13R	gateC21/spot34				
IFR	RTE	AAL4353	MD82	180	30	P1023	arr13R2	DFW13R310010
	DFW	13R	DFW13R	gateA35/spot24				
IFR	RTE	AAL336	B738	180	30	P1173	arr13R2	DFW13R310010
	DFW	13R	DFW13R	gateA26/spot14				
IFR	RTE	EGF4296	E135	180	30	P1301	arr13R2	DFW13R310010
	DFW	13R	DFW13R	gateA29/spot14				
IFR	RTE	AAL6351	MD82	180	30	P1531	arr13R2	DFW13R310010
	DFW	13R	DFW13R	gateA16/spot10				
IFR	RTE	COA1778	B752	180	30	P1797	arr13R2	DFW13R310010
	DFW	13R	DFW13R	gateE18/spot48				
IFR	RTE	AAL3956	MD83	180	30	P1857	arr13R2	DFW13R310010
	DFW	13R	DFW13R	gateA34/spot24				
IFR	RTE	AAL929	MD82	180	30	P2126	arr13R2	DFW13R310010
	DFW	13R	DFW13R	gateC35/spot44				
IFR	RTE	AAL2135	MD80	180	30	P2318	arr13R1	DFW13R310010
	DFW	13R	DFW13R	gateA11/spot5				
IFR	RTE	AAL3486	MD82	180	30	P2452	arr13R2	DFW13R310010
	DFW	13R	DFW13R	gateA17/spot10				
IFR	RTE	DAL8282	B737	180	30	P2650	arr13R2	DFW13R310010
	DFW	13R	DFW13R	gateE38/spot53				
IFR	RTE	AAL119	MD80	180	30	P79	arr17L2	DFW17L355010
	DFW	17L	DFW17L	gateA34/spot24				

IFR	RTE	AAL792	MD82	180	30	P292	arr17L2	DFW17L355010	DFW	17L	DFW17L	gateC11/spot32
IFR	RTE	DAL476	MD80	180	30	P512	arr17L1	DFW17L355010	DFW	17L	DFW17L	gateE14/spot46
IFR	RTE	COA1525	B733	180	30	P845	arr17L1	DFW17L355010	DFW	17L	DFW17L	gateE32/spot53
IFR	RTE	DAL6243	MD80	180	30	P1055	arr17L1	DFW17L355010	DFW	17L	DFW17L	gateE18/spot48
IFR	RTE	AAL6726	MD80	180	30	P1348	arr17L2	DFW17L355010	DFW	17L	DFW17L	gateA28/spot14
IFR	RTE	AAL4473	MD80	180	30	P1666	arr17L2	DFW17L355010	DFW	17L	DFW17L	gateA21/spot13
IFR	RTE	DAL2513	MD80	180	30	P1882	arr17L1	DFW17L355010	DFW	17L	DFW17L	gateE38/spot53
IFR	RTE	EGF4925	E145	180	30	P2105	arr17L2	DFW17L355010	DFW	17L	DFW17L	gateA23/spot14
IFR	RTE	AAL818	MD80	180	30	P2444	arr17L1	DFW17L355010	DFW	17L	DFW17L	gateC36/spot44
IFR	RTE	USA555	B733	180	30	P2640	arr17L1	DFW17L355010	DFW	17L	DFW17L	gateE17/spot46

Heavy 1: ATG Scenario file for the ‘Heavy 1’ run, consisting of 60 Arrivals, 64 Departures – **<u>SURFACE</u>** traffic

Row 1:
Rules, Status, Call Sign, Aircraft Type, Aircraft Speed, Altitude, Start Time, Sector ID, Init_point, Destination

Row 2:
Runway, Origin, Flight Plan, Orient, Gate/Spot, Beacon

IFR	GRD	DAL119	MD80	250	150	P90	DgateE38	gateE38	JAN
	17R	DFW	DFW.CLARE#.EIC..JAN			350	gateE38/spot47		
IFR	GRD	AAL194	B738	250	150	P104	DgateA33	gateA33	BOS
	17R	DFW	DFW.AKUNA#.MLC..BOS			310	gateA33/spot22		
IFR	GRD	AAL1614	B738	250	150	P108	DgateA34	gateA34	FWA
	17R	DFW	DFW.AKUNA#.MLC..FWA			330	gateA34/spot22		
IFR	GRD	AAL413	MD82	250	150	P115	DgateA23	gateA23	GGG
	17R	DFW	DFW.CLARE#.EIC..GGG			290	gateA23/spot15		
IFR	GRD	AAL2768	MD82	250	150	P123	DgateA12	gateA12	DTW
	17R	DFW	DFW.NOBLY#.LIT..DTW			190	gateA12/spot7		
IFR	GRD	AAL8637	MD82	250	150	P137	DgateC32	gateC32	MLU
	17R	DFW	DFW.SOLDO#.SOLDO..MLU			10	gateC32/spot42		
IFR	GRD	EGF4579	CRJ7	250	150	P147	DgateC11	gateC11	ABI
	18L	DFW	DFW.PODDE#.MQP..ABI			200	gateC11/spot31		
IFR	GRD	DAL554	MD80	250	150	P169	DgateE16	gateE16	BOS
	17R	DFW	DFW.TRISS#.TXK..BOS			250	gateE16/spot47		
IFR	GRD	EGF4726	E145	250	150	P188	DgateC10	gateC10	BLE
	18L	DFW	DFW.BLECO#.IRW..BLE			200	gateC10/spot22		
IFR	GRD	DAL368	MD80	250	150	P220	DgateE38	gateE38	AMA
	18L	DFW	DFW.FERRA#.PNH..AMA			350	gateE38/spot47		
IFR	GRD	AAL885	B738	250	150	P221	DgateA37	gateA37	SNA
	18L	DFW	DFW.PODDE#.MQP..SNA			350	gateA37/spot22		
IFR	GRD	AAL234	MD82	250	150	P247	DgateC33	gateC33	JAX
	17R	DFW	DFW.CLARE#.EIC..JAX			350	gateC33/spot42		
IFR	GRD	AAL663	B752	250	150	P276	DgateC14	gateC14	BTR
	17R	DFW	DFW.CLARE#.EIC..BTR			200	gateC14/spot31		
IFR	GRD	DAL127	MD80	250	150	P291	DgateE33	gateE33	PNS
	17R	DFW	DFW.CLARE#.EIC..PNS			300	gateE33/spot47		
IFR	GRD	DAL8731	MD80	250	150	P294	DgateE15	gateE15	LAW
	18L	DFW	DFW.FERRA#.PNH..LAW			250	gateE15/spot45		
IFR	GRD	AAL561	MD83	250	150	P317	DgateA9	gateA9	LIT
	17R	DFW	DFW.NOBLY#.LIT..LIT			170	gateA9/spot7		
IFR	GRD	DAL762	MD80	250	150	P350	DgateE38	gateE38	FLL
	17R	DFW	DFW.CLARE#.EIC..FLL			350	gateE38/spot47		
IFR	GRD	DAL5682	MD80	250	150	P356	DgateE9	gateE9	PIT
	17R	DFW	DFW.TRISS#.TXK..PIT			220	gateE9/spot45		
IFR	GRD	AAL9621	MD82	250	150	P419	DgateA16	gateA16	ORD
	17R	DFW	DFW.NOBLY#.LIT..ORD			190	gateA16/spot9		
IFR	GRD	AAL895	MD83	250	150	P452	DgateA12	gateA12	ORD
	17R	DFW	DFW.GRABE#.EAKER..ORD			190	gateA12/spot7		
IFR	GRD	USA2414	B752	250	150	P468	DgateE10	gateE10	BLE
	17R	DFW	DFW.GRABE#.EAKER..BLE			200	gateE10/spot45		
IFR	GRD	AAL521	MD82	250	150	P477	DgateC12	gateC12	PNS
	17R	DFW	DFW.CLARE#.EIC..PNS			200	gateC12/spot31		

IFR	GRD	AAL299	MD82	250	150	P557	DgateA13	gateA13	SJT
	18L	DFW	DFW.PODDE#.MQP..SJT			190	gateA13/spot7		
IFR	GRD	AAL92	B763	250	150	P576	DgateC22	gateC22	ATL
	17R	DFW	DFW.SOLDO#.SOLDO..ATL			270	gateC22/spot35		
IFR	GRD	AAL175	MD82	250	150	P621	DgateC27	gateC27	LBB
	18L	DFW	DFW.SLOTT#.TCC..LBB			280	gateC27/spot37		
IFR	GRD	AAL6968	MD82	250	150	P643	DgateC35	gateC35	BOS
	17R	DFW	DFW.TRISS#.TXK..BOS			350	gateC35/spot42		
IFR	GRD	DAL517	MD80	250	150	P643	DgateE8	gateE8	LAX
	18L	DFW	DFW.PODDE#.MQP..LAX			180	gateE8/spot42		
IFR	GRD	AAL8231	MD82	250	150	P680	DgateA17	gateA17	LAX
	18L	DFW	DFW.PODDE#.MQP..LAX			220	gateA17/spot9		
IFR	GRD	EGF4583	E145	250	150	P812	DgateA20	gateA20	DAY
	17R	DFW	DFW.NOBLY#.LIT..DAY			230	gateA20/spot11		
IFR	GRD	AAL7839	MD82	250	150	P916	DgateA18	gateA18	TYR
	17R	DFW	DFW.CLARE#.EIC..TYR			220	gateA18/spot9		
IFR	GRD	EGF4692	CRJ7	250	150	P992	DgateC15	gateC15	RSW
	17R	DFW	DFW.CLARE#.EIC..RSW			200	gateC15/spot31		
IFR	GRD	DAL698	MD80	250	150	P1044	DgateE17	gateE17	LGA
	17R	DFW	DFW.SOLDO#.SOLDO..LGA			270	gateE17/spot47		
IFR	GRD	EGF4185	CRJ7	250	150	P1058	DgateC17	gateC17	ABQ
	18L	DFW	DFW.CEOLA#.CNX..ABQ			230	gateC17/spot33		
IFR	GRD	EGF4927	E145	250	150	P1063	DgateC24	gateC24	ELP
	18L	DFW	DFW.PODDE#.MQP..ELP			270	gateC24/spot35		
IFR	GRD	AAL3741	B752	250	150	P1103	DgateA19	gateA19	ORD
	17R	DFW	DFW.GRABE#.EAKER..ORD			220	gateA19/spot9		
IFR	GRD	AAL957	MD82	250	150	P1104	DgateA21	gateA21	DEN
	18L	DFW	DFW.LOWGN#.LOWGN..DEN			270	gateA21/spot11		
IFR	GRD	UAL92	B744	250	150	P1116	DgateE11	gateE11	TYS
	17R	DFW	DFW.TRISS#.TXK..TYS			220	gateE11/spot45		
IFR	GRD	AAL71	B763	250	150	P1146	DgateC28	gateC28	TPA
	17R	DFW	DFW.CLARE#.EIC..TPA			300	gateC28/spot37		
IFR	GRD	DAL9774	MD80	250	150	P1181	DgateE18	gateE18	DTW
	17R	DFW	DFW.NOBLY#.LIT..DTW			270	gateE18/spot47		
IFR	GRD	AAL8575	B752	250	150	P1208	DgateC16	gateC16	LIT
	17R	DFW	DFW.NOBLY#.LIT..LIT			220	gateC16/spot31		
IFR	GRD	AAL45	B763	250	150	P1242	DgateC25	gateC25	STL
	17R	DFW	DFW.AKUNA#.MLC..STL			270	gateC25/spot35		
IFR	GRD	AAL9869	B752	250	150	P1271	DgateC29	gateC29	CID
	17R	DFW	DFW.GRABE#.EAKER..CID			300	gateC29/spot37		
IFR	GRD	AAL827	MD82	250	150	P1311	DgateC32	gateC32	GSO
	17R	DFW	DFW.TRISS#.TXK..GSO			10	gateC32/spot42		
IFR	GRD	AAL9397	MD82	250	150	P1319	DgateC19	gateC19	IND
	17R	DFW	DFW.NOBLY#.LIT..IND			220	gateC19/spot33		
IFR	GRD	USA64	A332	250	150	P1412	DgateE13	gateE13	PHL
	17R	DFW	DFW.TRISS#.TXK..PHL			220	gateE13/spot45		
IFR	GRD	AAL79	B763	250	150	P1502	DgateC27	gateC27	BOS
	17R	DFW	DFW.AKUNA#.MLC..BOS			280	gateC27/spot37		
IFR	GRD	AAL847	MD82	250	150	P1517	DgateC11	gateC11	CLE
	17R	DFW	DFW.NOBLY#.LIT..CLE			200	gateC11/spot31		
IFR	GRD	EGF4335	E145	250	150	P1522	DgateC33	gateC33	SDF
	17R	DFW	DFW.NOBLY#.LIT..SDF			350	gateC33/spot42		
IFR	GRD	AAL6244	MD82	250	150	P1636	DgateC26	gateC26	JAN
	17R	DFW	DFW.CLARE#.EIC..JAN			270	gateC26/spot35		
IFR	GRD	AAL998	MD82	250	150	P1672	DgateA22	gateA22	MIA
	17R	DFW	DFW.CLARE#.EIC..MIA			270	gateA22/spot15		

IFR	GRD	AAL218	B752	250	150	P1749	DgateC28	gateC28	GGG
	17R	DFW	DFW.CLARE#.EIC..GGG			300	gateC28/spot37		
IFR	GRD	DAL9238	MD80	250	150	P1772	DgateE21	gateE21	BWI
	17R	DFW	DFW.TRISS#.TXK..BWI			300	gateE21/spot47		
IFR	GRD	AAL8914	MD82	250	150	P1832	DgateA9	gateA9	AMA
	18L	DFW	DFW.FERRA#.PNH..AMA			170	gateA9/spot7		
IFR	GRD	EGF4797	E145	250	150	P1904	DgateA16	gateA16	CLT
	17R	DFW	DFW.SOLDO#.SOLDO..CLT			190	gateA16/spot9		
IFR	GRD	DAL995	MD80	250	150	P2003	DgateE14	gateE14	EWR
	17R	DFW	DFW.NOBLY#.LIT..EWR			250	gateE14/spot45		
IFR	GRD	AAL9489	MD83	250	150	P2034	DgateA10	gateA10	ABI
	18L	DFW	DFW.PODDE#.MQP..ABI			170	gateA10/spot7		
IFR	GRD	AAL9911	MD83	250	150	P2135	DgateA21	gateA21	PHL
	17R	DFW	DFW.TRISS#.TXK..PHL			270	gateA21/spot11		
IFR	GRD	DAL978	MD80	250	150	P2245	DgateE18	gateE18	ABQ
	18L	DFW	DFW.CEOLA#.CNX..ABQ			270	gateE18/spot47		
IFR	GRD	AAL788	MD83	250	150	P2263	DgateC30	gateC30	BWI
	17R	DFW	DFW.TRISS#.TXK..BWI			330	gateC30/spot37		
IFR	GRD	EGF4855	E145	250	150	P2413	DgateA11	gateA11	EWR
	17R	DFW	DFW.TRISS#.TXK..EWR			180	gateA11/spot7		
IFR	GRD	AAL614	B738	250	150	P2468	DgateA34	gateA34	FWA
	17R	DFW	DFW.AKUNA#.MLC..FWA			330	gateA34/spot22		
IFR	GRD	AAL4413	MD82	250	150	P2575	DgateA23	gateA23	GGG
	17R	DFW	DFW.CLARE#.EIC..GGG			290	gateA23/spot15		
IFR	GRD	AAL768	MD82	250	150	P2653	DgateA12	gateA12	DTW
	17R	DFW	DFW.NOBLY#.LIT..DTW			190	gateA12/spot7		

Heavy 2: ATG Scenario file for the 'Heavy 2' run, consisting of 60 Arrivals, 64 Departures – **AIRBORNE** traffic.

Row 1:
Rules, Status, Call Sign, Aircraft Type, Aircraft Speed, Altitude, Start Time, Sector ID, Init_point

Row2:
Airport, Runway, Flight Plan, Gate/Spot, Beacon

IFR	RTE	AAL3937	MD82	180	30	P28	arr17C4	DFW17C355010
	DFW	17C	DFW17C	gateC11/spot32				
IFR	RTE	AAL693	MD82	180	30	P149	arr17C4	DFW17C355010
	DFW	17C	DFW17C	gateC31/spot44				
IFR	RTE	AAL1876	MD83	180	30	P330	arr17C4	DFW17C355010
	DFW	17C	DFW17C	gateC20/spot34				
IFR	RTE	AAL156	B738	180	30	P505	arr17C4	DFW17C355010
	DFW	17C	DFW17C	gateC32/spot44				
IFR	RTE	AAL949	MD82	180	30	P680	arr17C4	DFW17C355010
	DFW	17C	DFW17C	gateC33/spot44				
IFR	RTE	AAL775	B752	180	30	P840	arr17C4	DFW17C355010
	DFW	17C	DFW17C	gateC29/spot36				
IFR	RTE	AAL8468	B752	180	30	P1003	arr17C3	DFW17C355010
	DFW	17C	DFW17C	gateA16/spot10				
IFR	RTE	AAL5871	MD80	180	30	P1157	arr17C3	DFW17C355010
	DFW	17C	DFW17C	gateA21/spot13				
IFR	RTE	AAL491	MD82	180	30	P1284	arr17C4	DFW17C355010
	DFW	17C	DFW17C	gateC12/spot32				
IFR	RTE	DAL2421	MD80	180	30	P1488	arr17C7	DFW17C355010
	DFW	17C	DFW17C	gateE34/spot53				
IFR	RTE	EGF4315	E145	180	30	P1662	arr17C3	DFW17C355010
	DFW	17C	DFW17C	gateA23/spot14				
IFR	RTE	AAL654	MD82	180	30	P1813	arr17C3	DFW17C355010
	DFW	17C	DFW17C	gateA22/spot13				
IFR	RTE	AAL322	B752	180	30	P2030	arr17C3	DFW17C355010
	DFW	17C	DFW17C	gateA24/spot14				
IFR	RTE	AAL5773	B752	180	30	P2214	arr17C4	DFW17C355010
	DFW	17C	DFW17C	gateC11/spot32				
IFR	RTE	AAL479	B752	180	30	P2320	arr17C4	DFW17C355010
	DFW	17C	DFW17C	gateC28/spot36				
IFR	RTE	DAL1635	MD80	180	30	P2428	arr17C7	DFW17C355010
	DFW	17C	DFW17C	gateE11/spot46				
IFR	RTE	EGF4247	E135	180	30	P2575	arr17C3	DFW17C355010
	DFW	17C	DFW17C	gateA38/spot24				
IFR	RTE	AAL9264	MD83	180	30	P109	arr18R2	DFW18R355010
	DFW	18R	DFW18R	gateC12/spot32				
IFR	RTE	EGF4244	E135	180	30	P215	arr18R2	DFW18R355010
	DFW	18R	DFW18R	gateA34/spot24				
IFR	RTE	DAL425	MD80	180	30	P588	arr18R2	DFW18R355010
	DFW	18R	DFW18R	gateE32/spot53				
IFR	RTE	AAL4526	MD80	180	30	P717	arr18R2	DFW18R355010
	DFW	18R	DFW18R	gateC35/spot44				
IFR	RTE	EGF4484	E145	180	30	P972	arr18R2	DFW18R355010
	DFW	18R	DFW18R	gateC32/spot44				

IFR	RTE	AAL735		MD82	180	30	P1202	arr18R2	DFW18R355010
	DFW	18R	DFW18R		gateC37/spot44				
IFR	RTE	UAL9196		A319	180	30	P1418	arr18R2	DFW18R355010
	DFW	18R	DFW18R		gateE20/spot48				
IFR	RTE	AAL244		MD80	180	30	P1731	arr18R1	DFW18R355010
	DFW	18R	DFW18R		gateA9/spot5				
IFR	RTE	UAL96		B772	180	30	P2052	arr18R2	DFW18R355010
	DFW	18R	DFW18R		gateE18/spot48				
IFR	RTE	AAL5882		MD83	180	30	P2210	arr18R2	DFW18R355010
	DFW	18R	DFW18R		gateC29/spot36				
IFR	RTE	AAL4811		MD82	180	30	P2367	arr18R2	DFW18R355010
	DFW	18R	DFW18R		gateC14/spot32				
IFR	RTE	DAL4594		MD80	180	30	P2596	arr18R2	DFW18R355010
	DFW	18R	DFW18R		gateE21/spot48				
IFR	RTE	AAL3556		MD82	180	30	P94	arr13R2	DFW13R310010
	DFW	13R	DFW13R		gateA21/spot13				
IFR	RTE	AAL3898		MD82	180	30	P408	arr13R2	DFW13R310010
	DFW	13R	DFW13R		gateC11/spot32				
IFR	RTE	UAL52		B763	180	30	P716	arr13R2	DFW13R310010
	DFW	13R	DFW13R		gateE13/spot46				
IFR	RTE	DAL2891		MD80	180	30	P857	arr13R2	DFW13R310010
	DFW	13R	DFW13R		gateE33/spot53				
IFR	RTE	EGF4845		E145	180	30	P1116	arr13R2	DFW13R310010
	DFW	13R	DFW13R		gateA35/spot24				
IFR	RTE	AAL6718		MD82	180	30	P1445	arr13R2	DFW13R310010
	DFW	13R	DFW13R		gateA37/spot24				
IFR	RTE	AAL599		MD80	180	30	P1746	arr13R2	DFW13R310010
	DFW	13R	DFW13R		gateC27/spot36				
IFR	RTE	DAL3728		MD80	180	30	P1944	arr13R2	DFW13R310010
	DFW	13R	DFW13R		gateE32/spot53				
IFR	RTE	EGF4169		E145	180	30	P2349	arr13R2	DFW13R310010
	DFW	13R	DFW13R		gateC30/spot36				
IFR	RTE	AAL7731		MD80	180	30	P2576	arr13R1	DFW13R310010
	DFW	13R	DFW13R		gateA10/spot5				
IFR	RTE	DAL224		MD80	180	30	P39	arr17L1	DFW17L355010
	DFW	17L	DFW17L		gateE11/spot46				
IFR	RTE	AAL3592		MD82	180	30	P167	arr17L1	DFW17L355010
	DFW	17L	DFW17L		gateC26/spot36				
IFR	RTE	AAL859		MD82	180	30	P312	arr17L1	DFW17L355010
	DFW	17L	DFW17L		gateC27/spot36				
IFR	RTE	AAL1231		B752	180	30	P486	arr17L1	DFW17L355010
	DFW	17L	DFW17L		gateC28/spot36				
IFR	RTE	AAL4268		MD83	180	30	P560	arr17L2	DFW17L355010
	DFW	17L	DFW17L		gateA23/spot14				
IFR	RTE	DAL2475		MD80	180	30	P663	arr17L1	DFW17L355010
	DFW	17L	DFW17L		gateE11/spot46				
IFR	RTE	UAL38		B772	180	30	P842	arr17L1	DFW17L355010
	DFW	17L	DFW17L		gateE18/spot48				
IFR	RTE	AAL174		B752	180	30	P978	arr17L2	DFW17L355010
	DFW	17L	DFW17L		gateA17/spot10				
IFR	RTE	EGF4333		E145	180	30	P1064	arr17L1	DFW17L355010
	DFW	17L	DFW17L		gateC36/spot44				
IFR	RTE	AAL4929		MD82	180	30	P1219	arr17L1	DFW17L355010
	DFW	17L	DFW17L		gateC20/spot34				
IFR	RTE	AAL6156		MD82	180	30	P1367	arr17L2	DFW17L355010
	DFW	17L	DFW17L		gateA36/spot24				

IFR	RTE	DAL139	MD80	180	30	P1477	arr17L1	DFW17L355010	DFW	17L	DFW17L	gateE35/spot53
IFR	RTE	EGF4848	CRJ7	180	30	P1562	arr17L1	DFW17L355010	DFW	17L	DFW17L	gateC26/spot36
IFR	RTE	EGF4912	CRJ7	180	30	P1677	arr17L1	DFW17L355010	DFW	17L	DFW17L	gateC33/spot44
IFR	RTE	EGF4414	E145	180	30	P1842	arr17L2	DFW17L355010	DFW	17L	DFW17L	gateA34/spot24
IFR	RTE	AAL422	MD80	180	30	P1956	arr17L2	DFW17L355010	DFW	17L	DFW17L	gateA16/spot10
IFR	RTE	AAL2912	MD82	180	30	P2143	arr17L2	DFW17L355010	DFW	17L	DFW17L	gateA17/spot10
IFR	RTE	AAL2941	B752	180	30	P2283	arr17L2	DFW17L355010	DFW	17L	DFW17L	gateA25/spot14
IFR	RTE	EGF4389	E145	180	30	P2381	arr17L1	DFW17L355010	DFW	17L	DFW17L	gateC32/spot44
IFR	RTE	DAL5135	MD80	180	30	P2528	arr17L1	DFW17L355010	DFW	17L	DFW17L	gateE36/spot53
IFR	RTE	DAL362	MD80	180	30	P2605	arr17L1	DFW17L355010	DFW	17L	DFW17L	gateE31/spot48

Heavy 2: ATG Scenario file for the ‘Heavy 2’ run, consisting of 60 Arrivals, 64 Departures – **SURFACE** traffic

Row 1:
Rules, Status, Call Sign, Aircraft Type, Aircraft Speed, Altitude, Start Time, Sector ID, Init_point, Destination

Row 2:
Runway, Origin, Flight Plan, Orient, Gate/Spot, Beacon

IFR	GRD	DAL8479	MD80	250	150	P90	DgateE38	gateE38	FSM
	17R	DFW	DFW.AKUNA#.MLC..FSM			350	gateE38/spot47		
IFR	GRD	EGF4375	E145	250	150	P131	DgateA34	gateA34	MCO
	17R	DFW	DFW.CLARE#.EIC..MCO			330	gateA34/spot22		
IFR	GRD	AAL252	B763	250	150	P158	DgateA21	gateA21	BWI
	17R	DFW	DFW.TRISS#.TXK..BWI			270	gateA21/spot11		
IFR	GRD	DAL76	B763	250	150	P212	DgateE16	gateE16	TYS
	17R	DFW	DFW.TRISS#.TXK..TYS			250	gateE16/spot47		
IFR	GRD	AAL6358	B737	250	150	P259	DgateC22	gateC22	ATL
	17R	DFW	DFW.SOLDO#.SOLDO..ATL			270	gateC22/spot35		
IFR	GRD	AAL358	MD82	250	150	P265	DgateC32	gateC32	ATL
	17R	DFW	DFW.SOLDO#.SOLDO..ATL			10	gateC32/spot42		
IFR	GRD	EGF4147	E135	250	150	P274	DgateA23	gateA23	SGF
	17R	DFW	DFW.AKUNA#.MLC..SGF			290	gateA23/spot15		
IFR	GRD	EGF4666	E145	250	150	P285	DgateA16	gateA16	LAX
	18L	DFW	DFW.CEOLA#.CNX..LAX			190	gateA16/spot9		
IFR	GRD	EGF4982	E145	250	150	P293	DgateC11	gateC11	DTW
	17R	DFW	DFW.NOBLY#.LIT..DTW			200	gateC11/spot31		
IFR	GRD	COA364	B735	250	150	P345	DgateE18	gateE18	PIA
	17R	DFW	DFW.AKUNA#.MLC..PIA			270	gateE18/spot47		
IFR	GRD	DAL4977	MD80	250	150	P347	DgateE15	gateE15	LAX
	18L	DFW	DFW.CEOLA#.CNX..LAX			250	gateE15/spot45		
IFR	GRD	DAL284	MD80	250	150	P351	DgateE9	gateE9	LEX
	17R	DFW	DFW.TRISS#.TXK..LEX			220	gateE9/spot45		
IFR	GRD	EGF4342	E145	250	150	P389	DgateC20	gateC20	OKC
	18L	DFW	DFW.BLECO#.IRW..OKC			270	gateC20/spot33		
IFR	GRD	EGF4383	E145	250	150	P389	DgateC24	gateC24	XNA
	17R	DFW	DFW.AKUNA#.MLC..XNA			270	gateC24/spot35		
IFR	GRD	AAL2537	B738	250	150	P455	DgateC12	gateC12	STL
	17R	DFW	DFW.AKUNA#.MLC..STL			200	gateC12/spot31		
IFR	GRD	UAL223	B752	250	150	P463	DgateE10	gateE10	MIA
	17R	DFW	DFW.CLARE#.EIC..MIA			200	gateE10/spot45		
IFR	GRD	AAL87	B763	250	150	P509	DgateC25	gateC25	MIA
	17R	DFW	DFW.CLARE#.EIC..MIA			270	gateC25/spot35		
IFR	GRD	AAL7836	MD82	250	150	P519	DgateC17	gateC17	LIT
	17R	DFW	DFW.NOBLY#.LIT..LIT			230	gateC17/spot33		
IFR	GRD	EGF4237	E145	250	150	P580	DgateA33	gateA33	SHV
	17R	DFW	DFW.SOLDO#.SOLDO..SHV			310	gateA33/spot22		
IFR	GRD	AAL572	MD82	250	150	P581	DgateC14	gateC14	SDF
	17R	DFW	DFW.NOBLY#.LIT..SDF			200	gateC14/spot31		
IFR	GRD	AAL8565	MD82	250	150	P654	DgateC21	gateC21	MSN
	17R	DFW	DFW.AKUNA#.MLC..MSN			270	gateC21/spot33		
IFR	GRD	AAL996	MD82	250	150	P680	DgateA20	gateA20	MKE
	17R	DFW	DFW.AKUNA#.MLC..MKE			230	gateA20/spot11		

IFR	GRD	AAL915	MD82	250	150	P706	DgateC15	gateC15	LGA
	17R	DFW	DFW.NOBLY#.LIT..LGA			200	gateC15/spot31		
IFR	GRD	DAL7773	MD80	250	150	P762	DgateE13	gateE13	XNA
	17R	DFW	DFW.AKUNA#.MLC..XNA			220	gateE13/spot45		
IFR	GRD	EGF4599	E145	250	150	P806	DgateA22	gateA22	MLU
	17R	DFW	DFW.SOLDO#.SOLDO..MLU			270	gateA22/spot15		
IFR	GRD	AAL8129	MD82	250	150	P837	DgateC27	gateC27	FLL
	17R	DFW	DFW.CLARE#.EIC..FLL			280	gateC27/spot37		
IFR	GRD	USA9283	B752	250	150	P888	DgateE14	gateE14	BLE
	17R	DFW	DFW.GRABE#.EAKER..BLE			250	gateE14/spot45		
IFR	GRD	EGF4844	E135	250	150	P933	DgateA23	gateA23	CLT
	17R	DFW	DFW.SOLDO#.SOLDO..CLT			290	gateA23/spot15		
IFR	GRD	AAL5829	MD82	250	150	P1006	DgateC19	gateC19	CMH
	17R	DFW	DFW.NOBLY#.LIT..CMH			220	gateC19/spot33		
IFR	GRD	FFT7347	A319	250	150	P1006	DgateE11	gateE11	BOS
	17R	DFW	DFW.AKUNA#.MLC..BOS			220	gateE11/spot45		
IFR	GRD	EGF4365	E145	250	150	P1012	DgateA35	gateA35	MSY
	17R	DFW	DFW.CLARE#.EIC..MSY			330	gateA35/spot22		
IFR	GRD	EGF4441	E135	250	150	P1031	DgateC35	gateC35	BLE
	17R	DFW	DFW.GRABE#.EAKER..BLE			350	gateC35/spot42		
IFR	GRD	EGF4854	E145	250	150	P1121	DgateC11	gateC11	IND
	17R	DFW	DFW.NOBLY#.LIT..IND			200	gateC11/spot31		
IFR	GRD	AAL1565	MD83	250	150	P1134	DgateA39	gateA39	ORF
	17R	DFW	DFW.TRISS#.TXK..ORF			350	gateA39/spot22		
IFR	GRD	AAL989	MD82	250	150	P1138	DgateA39	gateA39	SGF
	17R	DFW	DFW.AKUNA#.MLC..SGF			350	gateA39/spot22		
IFR	GRD	DAL274	MD80	250	150	P1148	DgateE5	gateE5	BLE
	18L	DFW	DFW.BLECO#.IRW..BLE			170	gateE5/spot42		
IFR	GRD	EGF4733	E145	250	150	P1163	DgateC26	gateC26	LGA
	17R	DFW	DFW.TRISS#.TXK..LGA			270	gateC26/spot35		
IFR	GRD	AAL98	B763	250	150	P1213	DgateA24	gateA24	LIT
	17R	DFW	DFW.NOBLY#.LIT..LIT			290	gateA24/spot15		
IFR	GRD	AAL4277	MD82	250	150	P1239	DgateA37	gateA37	SJC
	18L	DFW	DFW.CEOLA#.CNX..SJC			350	gateA37/spot22		
IFR	GRD	AAL7531	MD82	250	150	P1256	DgateC12	gateC12	SHV
	17R	DFW	DFW.SOLDO#.SOLDO..SHV			200	gateC12/spot31		
IFR	GRD	DAL2225	MD80	250	150	P1273	DgateE6	gateE6	JAS
	18L	DFW	DFW.JASPA#.JASPA..JAS			170	gateE6/spot42		
IFR	GRD	AAL142	B738	250	150	P1312	DgateA21	gateA21	BTR
	17R	DFW	DFW.CLARE#.EIC..BTR			270	gateA21/spot11		
IFR	GRD	AAL973	MD82	250	150	P1350	DgateC27	gateC27	LEX
	17R	DFW	DFW.TRISS#.TXK..LEX			280	gateC27/spot37		
IFR	GRD	EGF4597	E145	250	150	P1355	DgateA38	gateA38	PHX
	18L	DFW	DFW.PODDE#.MQP..PHX			350	gateA38/spot22		
IFR	GRD	AAL67	B763	250	150	P1433	DgateA29	gateA29	BNA
	17R	DFW	DFW.TRISS#.TXK..BNA			330	gateA29/spot15		
IFR	GRD	AAL6439	B752	250	150	P1434	DgateC16	gateC16	ELD
	17R	DFW	DFW.SOLDO#.SOLDO..ELD			220	gateC16/spot31		
IFR	GRD	AAL215	MD80	250	150	P1506	DgateC28	gateC28	MSY
	17R	DFW	DFW.CLARE#.EIC..MSY			300	gateC28/spot37		
IFR	GRD	AAL475	MD82	250	150	P1516	DgateC32	gateC32	LAS
	18L	DFW	DFW.CEOLA#.CNX..LAS			10	gateC32/spot42		
IFR	GRD	AAL1334	MD82	250	150	P1551	DgateC20	gateC20	ORD
	17R	DFW	DFW.GRABE#.EAKER..ORD			270	gateC20/spot33		
IFR	GRD	AAL18	B763	250	150	P1601	DgateC11	gateC11	EWR
	17R	DFW	DFW.NOBLY#.LIT..EWR			200	gateC11/spot31		

IFR	GRD	DAL496	MD80	250	150	P1607	DgateE8	gateE8	CID
	17R	DFW	DFW.GRABE#.EAKER..CID			180	gateE8/spot42		
IFR	GRD	DAL686	MD80	250	150	P1631	DgateE11	gateE11	MSY
	17R	DFW	DFW.CLARE#.EIC..MSY			220	gateE11/spot45		
IFR	GRD	EGF4737	E135	250	150	P1714	DgateA23	gateA23	SGF
	17R	DFW	DFW.AKUNA#.MLC..SGF			290	gateA23/spot15		
IFR	GRD	EGF4567	E145	250	150	P1805	DgateA16	gateA16	LAX
	18L	DFW	DFW.CEOLA#.CNX..LAX			190	gateA16/spot9		
IFR	GRD	AAL794	MD82	250	150	P1817	DgateC33	gateC33	ATL
	17R	DFW	DFW.SOLDO#.SOLDO..ATL			350	gateC33/spot42		
IFR	GRD	DAL9565	MD80	250	150	P1921	DgateE18	gateE18	CLT
	17R	DFW	DFW.SOLDO#.SOLDO..CLT			270	gateE18/spot47		
IFR	GRD	AAL6913	MD80	250	150	P1989	DgateC35	gateC35	EWR
	17R	DFW	DFW.TRISS#.TXK..EWR			350	gateC35/spot42		
IFR	GRD	AAL278	B738	250	150	P2136	DgateA17	gateA17	LGA
	17R	DFW	DFW.AKUNA#.MLC..LGA			220	gateA17/spot9		
IFR	GRD	DAL8999	B738	250	150	P2202	DgateE32	gateE32	MSN
	17R	DFW	DFW.AKUNA#.MLC..MSN			300	gateE32/spot47		
IFR	GRD	EGF4175	E145	250	150	P2391	DgateA34	gateA34	MCO
	17R	DFW	DFW.CLARE#.EIC..MCO			330	gateA34/spot22		
IFR	GRD	AAL52	B763	250	150	P2489	DgateA21	gateA21	BWI
	17R	DFW	DFW.TRISS#.TXK..BWI			270	gateA21/spot11		
IFR	GRD	AAL396	MD82	250	150	P2502	DgateC32	gateC32	TXK
	17R	DFW	DFW.TRISS#.TXK..TXK			10	gateC32/spot42		
IFR	GRD	AAL992	MD82	250	150	P2619	DgateC29	gateC29	CLT
	17R	DFW	DFW.TRISS#.TXK..CLT			300	gateC29/spot37		
IFR	GRD	AAL323	B752	250	150	P2641	DgateA18	gateA18	LIT
	17R	DFW	DFW.NOBLY#.LIT..LIT			220	gateA18/spot9		

APPENDIX H: HUMAN FACTORS QUESTIONNAIRES

The following set of questionnaires was administered to the controller and pseudo-pilot subjects during the April–May 2010 data collection runs at the FutureFlight Central (FFC) facility.

Controller Workload Questionnaire

The following questions were answered on a laptop computer immediately after each trial in the Spot and Runway Departure Advisor (SARDA) experiment. Questions were answered by clicking a mouse along a non-numbered horizontal scale from low (left anchor) to high (right anchor).

1. How much **mental activity** was required in the last run (e.g., thinking, deciding, calculating, remembering, looking, searching, etc.)?

2. How much **physical activity** (e.g., use of radios, keyboard, mouse, etc.) was required during this run?

3. How **successful** do you think you were in accomplishing the goals of the task during this run?

4. How **hard did you have to work** (mentally and physically) to accomplish this level of success?

5. How **frustrated** were you during this run?

6. How much **time pressure** did you feel due to the pace of events during the run? Was the pace slow and leisurely or rapid and frantic?

Controller Subjective Situation Awareness Questionnaire

The following questions were answered on a laptop computer immediately after each trial in the SARDA experiment. Questions were answered using a 1–4 scale (1= very difficult/very poor, 4 = very easy/very well).

Please rate your ability to identify the information you needed to control traffic during this run.

1. How well did you understand what was going on during this run?

2. How well could you predict what event was about to occur next during this run?

3. Did you know how to best achieve your goal during this run?

4. How easy or difficult—in terms of mental effort required—was it for you to identify or detect the information you needed to control traffic during this run?

5. How easy or difficult—in terms of mental effort—was it to understand what was going on during this run?

6. How easy or difficult—in terms of mental effort—was it to predict what event was about to occur next during this run?

7. How easy or difficult—in terms of mental effort—was it to decide on how best to achieve your goals during this run?

Controller Objective Situation Awareness Questionnaire

The following questions were answered on a laptop computer immediately after each trial in the SARDA experiment. Which questions were asked depended on the role (i.e., ground/local) played by the controller during that trial. Questions were answered using keyboard text entries. All questions were scored as either correct or incorrect. Scoring criteria (e.g., when a range/ approximation rather than an exact value was considered correct) are included in parentheses after each question.

Ground

1. Which aircraft should you release next from the spot?
2. What is the departure fix of the last aircraft you released from the spot?
3. How many aircraft are currently in the departure queue (+/- 1 aircraft of actual)?
4. Which spots are backing up (i.e., more than two aircraft waiting)?
5. What percentage of spots are open (+/- 10 percent of actual)?

Local

1. How many arrivals do you have on final?
2. What is the initial departure fix of the next departing aircraft?
3. Where is the next departing aircraft?
4. How many heavies are in queue?
5. How far out is your last departure (could include “on runway” or “off scope,” in addition to mile estimate)?
6. How much farther does your last departure need to travel before the next one can be released?
7. Is the runway clear for a departure?
8. How many arrivals are holding short of 17R?

Pseudo-Pilot Workload Questionnaire

Questions 1–6 were answered on a printed sheet immediately after each trial in the SARDA experiment. Questions were answered by circling a number on a 7-point scale (1 = low, 7 = high). Question 7 was answered by filling in a percentage value for each sub-question.

1. How much mental activity was required in the last run (e.g., thinking, deciding, calculating, remembering, looking, searching, etc.)?

2. How much physical activity (e.g., use of radios, keyboard, mouse, etc.) was required during this run?

3. How successful do you think you were in accomplishing the goals of the task during this run?

4. How hard did you have to work (mentally and physically) to accomplish this level of success?

5. How frustrated were you during this run?

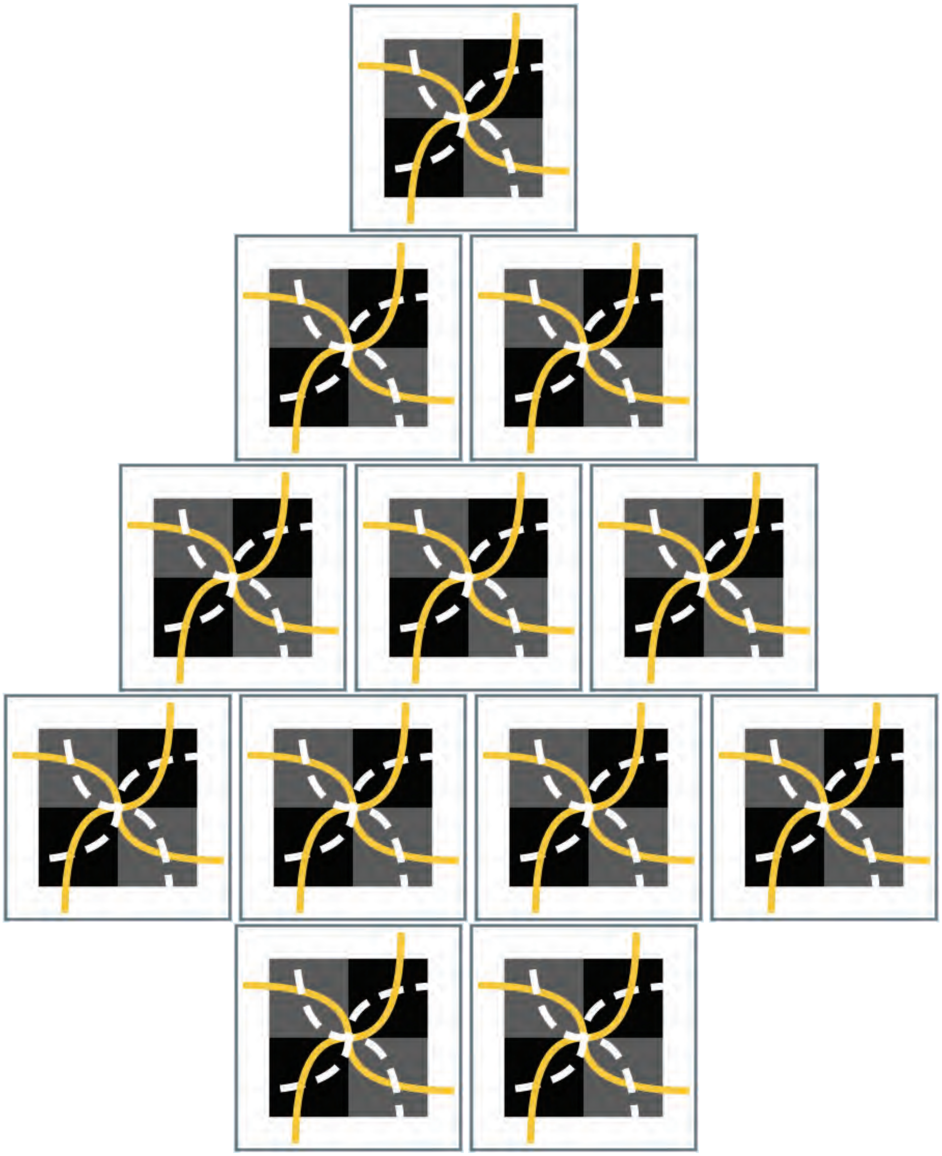
6. How much time pressure did you feel due to the pace of events during the run? Was the pace slow and leisurely or rapid and frantic?

7. Please estimate the percent that each of the following factors contributed to your total workload during this run (total across all factors should be 100%).
   a. Number of aircraft under my control
   b. Size of the area under my control
   c. Communications with ATC
   d. Executing ATC commands
   e. Issues with the screen/map display

APPENDIX I: DISTRIBUTED SURFACE MANAGEMENT GOVERNANCE MODEL (DISSEMINATE), CONCEPTUAL WHITE PAPER

This section includes a white paper describing a potential extrapolation of the modular design approach implemented in the Spot and Runway Departure Advisor (SARDA) project, extending the singular airport to multiple neighboring airports, as exemplify in the Metroplex concept.[1]

[1] Metroplex represents congested airspace located about a metropolitan area that exhibits a high degree of interaction between two or more major airports.
Clark, J.; Ren, L.; Schleicher, D.; Crisp, D.L.; Gutterud, R.; Thompson, T.; Cross, C.; and Lewis, T.B.: Characterization of and Concepts for Metroplex Operations. NASA/CR-2011-216414, July 2011.



Distributed Surface Management Governance Model (DISSEMINATE)

Conceptual White Paper

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1. BACKGROUND

The Safe and Efficient Surface Operations (SESO) research focus area (RFA) is tasked with investigating optimization techniques to improve ground movement efficiency. The algorithms will include modeling of uncertainty in scheduling events without impinging upon safety. Furthermore, environmental impact factors such as emissions, particulate matter, noise, and fuel burn will need to be integrated into the optimization process. Altogether, the solution needs to take into consideration three major constraining factors: safety, uncertainty, and environmental impacts.

Secondary factors, such as airlines' requests and collaboration with other decision support tools (DSTs) will be address at a later time. Ascertaining an optimized solution for each factor is achievable with some degree of effort, depending on the level of desired fidelity and output requirements. However, finding an optimized solution that satisfies all three factors while providing viable advisories in real time is a major challenge to researchers in this domain. The real-time solution is of paramount importance when having the human operators interacting with the system to control traffic. The real-time requirement is relaxed during initial research phases.

To date, the SESO research team has been actively working on building optimizers for the taxi scheduler, spot release advisor, and runway scheduler. A fast-time simulator, Surface Optimization Simulator and Scheduler (SOSS), has been constructed to prototype, verify, and validate the functionality (ref. 1). SOSS allows for rapid prototyping and analysis of initial trends offered by the algorithms. When a design goal is reached, the algorithm gets migrated into the real-time simulator for further analysis.

A real-time, high-fidelity simulator is being developed to accommodate human operators and gain valuable feedback on topics like workability, feasibility, and usability. The real-time simulator is capable of systematic introduction of uncertainty modeling, like variation in taxi speed and aircraft activation time. The re-architected Surface Management System (SMS) software employs a plug-in architecture to facilitate the development, integration, testing, and contrasting of various algorithms.[1] The SMS plug-in architecture is key to assisting the researchers with developing and testing variations of scheduling and taxiing algorithms.

From a system architecture perspective, the plug-in SMS architecture allows for great flexibility in system development. It allows for concurrent development of similar-type modules by NASA, the Federal Aviation Administration (FAA), or any other organizations. The common or core SMS architecture can accommodate various plug-in modules, allowing for easy reconfiguration of the tool to support different objectives. It can be configured as a pure research tool, a Decision Support Tool (DST) for operational use, or as a prototype system mixing operational modules with research modules.

A primary consideration for future air transportation needs is the requirement to control up to three times current-day traffic, as specified by the Joint Planning and Development Office (JPDO). The increase in traffic is expected to add additional burden on the computational engine (COGINE) to deliver a viable solution in real time. In an era of three times the current demand, how can a surface

[1] The SMS plug-in architecture is available in SMS version 8.4 on the NASA codebase.

automation tool be deployed to compliment the human workforce during nominal and off-nominal conditions? One school of thought suggests that the system be fully automated while, at the other end of the spectrum, the human still occupies the decision-making role. The third option falls somewhere between the two extremes whereby the human will interact with more sophisticated automation systems. All the proposed role changes will require modifications to current-day operational procedures and aircraft (control) ownership structure.

The development and deployment of an advanced surface automation system that produces optimized schedules using environmental, safety, uncertainty, and timely calculated results are the inspiration for this white paper. It is the convergence of these weighty factors that forces the examination of using a distributed system. The distributed framework is expected to provide a mechanism where the objectives can be met in real time.

The *Distributed Surface Management Governance Model* (*DISSEMINATE*) framework sets out to address the following factors: computational efficiency (real time), flexible and robust system configuration, integration and harmonization of human and automation, and system recovery.

This white paper is broken down into three sections. The first section defines the need for such a distributed model. The next section defines the proposed architecture for the surface domain, and the last section provides sample applications of the benefits of the flexible framework.

2. THE DISTIBUTED SURFACE MANAGEMENT GOVERNANCE MODEL (DISSEMINATE)

2.1 Objectives and Requirements

The SMS architecture provides an appropriate level of situation awareness to assist traffic management coordinators with a current-day level of traffic. However, the architecture may not offer enough robustness with the expected increase in traffic and complexity of computation. The DISSEMINATE concept proactively proposes a notional architecture and governance model that sets out to address anticipated system performance bottlenecks and limitations due to increase of demand and incorporation of more stringent requirements.

In addition, the governance model provides a platform to investigate the human-automation interaction, such as roles and responsibility, and the transfer of authority between humans and automation. Furthermore, the distributed model is designed for scalability and can provide a framework for examination of Metroplex operations with prospective integration into the terminal and en route domains (refs. 2,3).

To meet the goals outlined above, DISSEMINATE will: 1) architect a framework that promotes computational efficiency; 2) provide a robust, configurable, and scalable architecture to provide research into multiple domains; 3) construct an environment to investigate the roles of the humans and automation (*interactive mode*, *training mode*, and *system recovery mode* are discussed in following sections).

2.2 Characteristics of DISSEMINATE

The overarching design of the DISSEMINATE model is its modularity. The modularity is carried through the entire architecture from the subsystem, the system, and throughout the distributed system. Its core architecture is designed for ***efficiency and extensibility***. The distributed architecture developed for the Multi-Center Traffic Management Advisor (McTMA) is used as a template in developing the DISSEMINATE framework (refs. 4-7). Key characteristics include a distributed network, facilitation of collaboration and coordination between adjacent control units, and providing multiple levels of control over the system for dealing with localized or regional problems.

The DISSEMINATE framework is envisioned to provide a robust platform to support advance research in the surface domain such as ground taxi optimization, with possible extension to nearby airports. The research objectives and problems are quite different between McTMA and DISSEMINATE systems, but the distributed (metering capability) are common objectives to both systems.

2.2.1 Computational Efficiency and Real-Time Requirements

Finding an optimized solution can be a computationally intensive task. Calculating optimized taxi solutions for many aircraft in real time at frequent update rates can push the system to its limit. Therefore, computational efficiency plays a major factor when the system is used in a real-time environment (as a decision support tool). The real-time interactive requirement also places a sizable barrier to acquiring a solution. There are ways to overcome such hurdles, like obtaining faster hardware (brute force), reducing the fidelity of the model (using heuristics), and applying more efficient coding standards.

DISSEMINATE takes an approach that retains the complexity and fidelity of the problem but breaks it down into more manageable segments. The approach takes the stance that as the complex problem domain is scaled down into smaller segments, the algorithm will have a better probability of producing a workable solution in real time. The tradeoff may require more hardware (not top-of-the-line central processing units (CPUs)) to calculate the sub-unit problems, but may provide more realistic deployment of the system (reduced cost). The most powerful piece of hardware in the suite can be used to solve the most intensive tasks while less powerful computers can solve ancillary and non-time-critical duties. Scale the hardware requirements to the needs of the facility.

2.2.2 Extensibility

DISSEMINATE is built upon a very flexible and modular framework. The framework is designed with extensibility and scalability in mind. This capability can be extremely useful to both operational and research groups. Extensibility allows researchers to investigate multiple variations in concept, or distinct concepts, which may be complementary to one another. Scalability refers to the architecture's ability to add or delete components when adapted at larger or smaller airports. Scalability also means if more than one instance of DISSEMINATE is operational, they can be integrated to govern a larger domain.

These two characteristics are built into the foundational architecture of the system. This core characteristic is carried throughout the framework, affecting designs of the subsystem's computational engine (COGINE), system, and extended network. The concept of COGINE is defined in section 2.4. Section 3 shows how a Metroplex can be modeled using the DISSEMINATE framework. The subsystem can accommodate new technology or improved modeling components, as they become available. Such components may include taxi scheduling, runway balancing, noise and emission modeling, and weather forecasting. Refer to section 2.4, the Computational Engine (COGINE), for more details.

The modularity also allows for the concurrent development of similarly functional components. These components can have similar, different, or complimentary functions, and yet all can coexist and interact with each other. However, the users or researchers do need to set guidelines for the level of interaction and the nature of the collaboration. Operationally, the design of the distributed systems will depend on the needs of the facility and may be restricted by the physical limitations of the airport, Air Traffic Control (ATC) facility, and controllable domain, to name a few examples. In the laboratory, this extensibility characteristic allows researchers to investigate alternative concepts and out-the-box thinking by designing subsystems within DISSEMINATE that can be interchangeably replaced without reduced effort and downtime.

2.2.3 Human and Automation Integration

Proof of concept test runs in a simulator can uncover hidden or unforeseen situations. DISSEMINATE is well suited for this purpose, as well as being a training tool, and a mechanism to systematically investigate transfer of authority between automation and the human operator during highly congested traffic conditions.

Built upon the current SMS baseline, DISSEMINATE is expected to be able to operate in a simulation environment. The capability exists today for SMS to operate with the users during human-in-the-loop (HITL) runs. Likewise, the system can be configured to accommodate and complement human operator actions, while certain tasks are totally controlled by the automation. This human-automation model has already been used extensively to validate other concepts (ref. 4). DISSEMINATE retains this feature. Like SMS, DISSEMINATE also operates as a real-time system.

With little effort, the simulation environment can be transformed into a training class where controllers can come in to sharpen their skills. DISSEMINATE can be configured to control most aspects of the airport while allowing the trainee to control other aspects of the domain, like taxi route movement during training. The modular framework of DISSEMINATE is designed to support such scenarios. But this capability can offer up an even more ingenious application during operational use. DISSEMINATE's modular framework offers a technique to reintroduce the human operator into a highly automated and congestion environment if a subsystem becomes inoperative. The solution looks very much like a training scenario where the downed subsystem is replaced with a human operator. DISSEMINATE can start the recovery process by issuing more conservative constraints to automation units, which abuts the domain of the human operator (see section 3.3 for more details). Efficiency is expected to diminish, but may allow for the interjection of the human operator to control the problem. This feature may also provide a great vehicle for further research.

2.3 The DISSEMINATE Architecture

The DISSEMINATE framework aims to build upon an existing tool, the Surface Management System (SMS). The SMS has significance because it is the tool NASA currently uses to conduct surface optimization research. It is envisioned that the DISSEMINATE architecture will supersede that of the SMS architecture while fully capitalizing on its modular plug-in design.[2] All current algorithmic developments and activities can be carried forward. SMS provides the basic architecture to obtain data feeds and routing of user display visuals. DISSEMINATE aims to capitalize on the current SMS modular framework by promoting more data sharing between subsystems and other instances of the DISSEMINATE system, like that of the Metroplex (refs. 2,3).

DISSEMINATE tackles the complex and intensive surface optimization solution by employing elegant design rather than applying brute force. The model partitions the complex surface domain into smaller segments where the various optimizers and COGINEs can produce solutions quicker. Conceptually, the smaller domain segments (which can be modeled to represent the control points in the physical world) are mapped to a COGINE that computes solutions for that domain. The COGINE thus becomes a proxy for the physical world. The COGINE works independently to solve localized problems and coordinates with adjacent COGINEs to offer collaborative solutions. A COGINE is a construct used to represent the division of a larger problem, breaking it down to sub-problems and collaboratively working toward a solution. Hence, the COGINE can represent any of the identified functionalities of the airport surface.

The SMS architecture (up to version 8.3) uses a centralized approach to attack every aspect of the airport problem (fig. I.1). It employs a single instance of SMS to devise a solution for the entire airport. The singular approach needs to change to offer more robustness and satisfy the research objectives.

As an example of using DISSEMINATE, the airport domain is strategically divided into smaller sub-domains. Calculation efficiency can be gained by optimizing over a smaller area of the airport (fig. I.2). The actual creation of the sub-domain sectors at any particular airport is left as an exercise for others to pursue. Figure I.2 shows one possible representation for the DFW airport. However, there are some important parameters that can influence the acceptability and usability of the design. Factors such as the location of change in control (handoff), geographic demarcation, environmental restrictions, and historically high workload areas should be taken into consideration during the design process. Any critical fallback procedure should also be considered, such as when a human needs to interject and take over control of a degraded (situation) area while collaboratively working with automation, which still controls adjacent areas.

This piecemeal collaboration, or modular approach, has been tried once before in the en route domain. The multi-center traffic management advisor (McTMA) adapted the distributed computing model to address the extended and regional nature of controlling congested traffic in the northeast into the Philadelphia airport. The four McTMA systems were configured to meet the needs of the Air Traffic Management (ATM) operator, and constraints of the airspace and system. The systems

[2] The SMS versions 8.4 and 9.x have implemented modular design architecture to support various components such as schedulers and planners. DISSIMINATE also capitalizes on this new architecture.

helped increase situational awareness beyond the current center, improve communication, and foster collaboration between the four centers, Philadelphia Terminal Radar Approach Control (TRACON), and the ATC System Command Center (ref. 8).

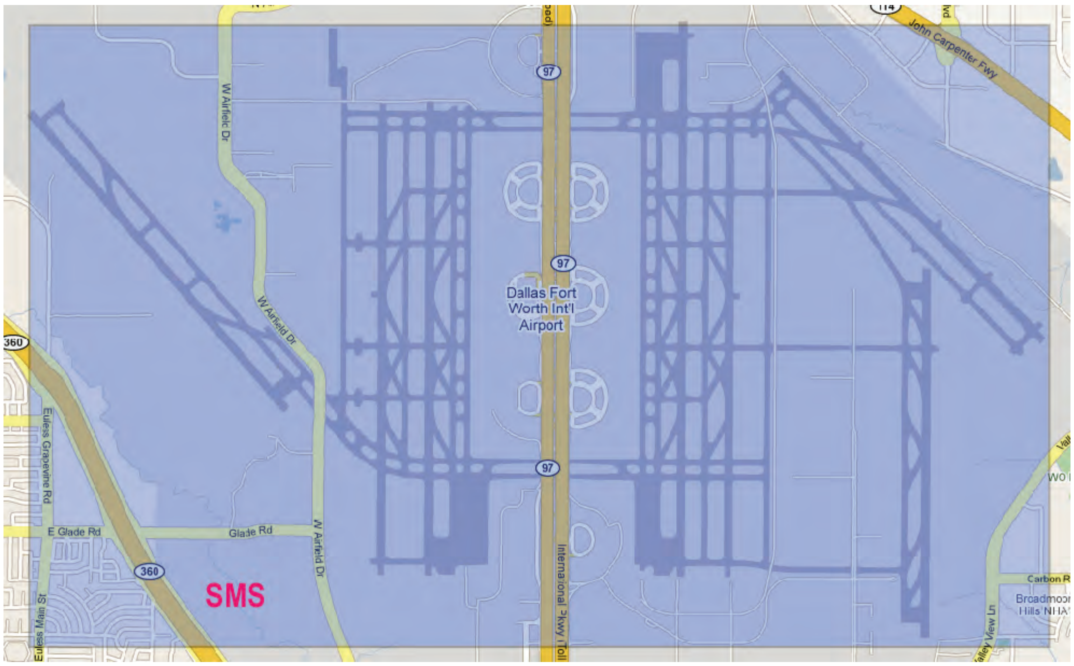


Figure I.1: SMS providing coverage and optimized solution for all regions of the DFW airport (shaded blue overlay region).

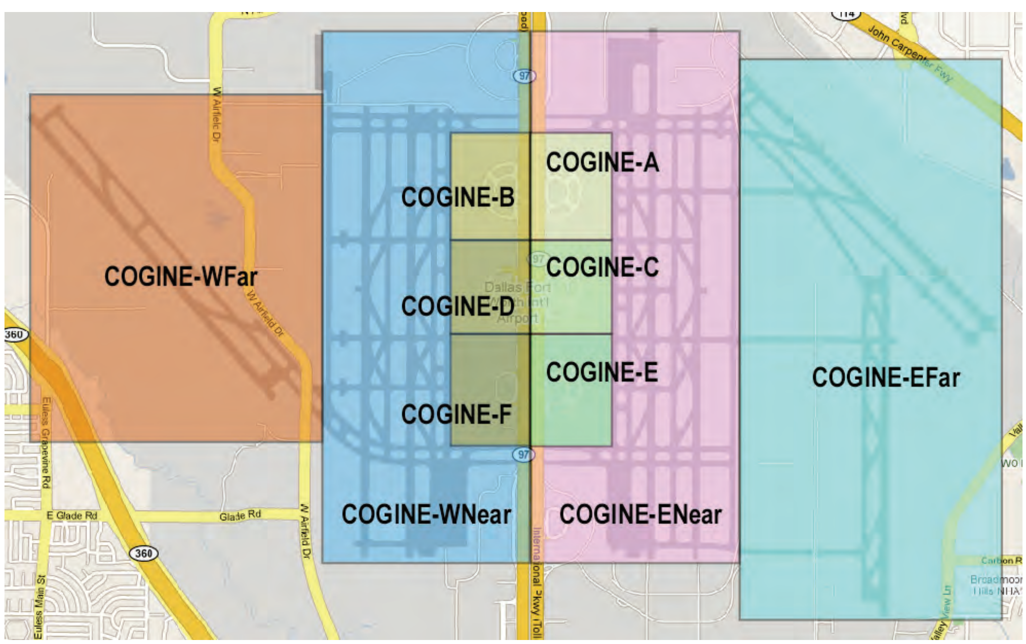


Figure I.2: Notional configuration and deployment of the computational engines (COGINEs) at the DFW airport.

The basic distributed system architecture and communication protocol learned from the McTMA system will integrate into the DISSEMINATE model. Conceptually, there are many similarities between the en route and surface model. SMS uses the node-link model to describe the taxi route on the surface. In the en route, McTMA uses air routes (links) and a scheduling complex (nodes with built-in scheduling functions). A scheduling complex is similar in functionality to a COGINE, both controlling a subset of the larger picture while being cognizant of the behavior of its neighboring schedulers.

Figure I.2 shows a sample deployment of multiple COGINEs at DFW. This figure shows the use of ten COGINEs covering the various movement areas on the airport. But as shown in figure I.3, the complete system contains 17 COGINEs, the ten in figure I.2 plus seven environmental pieces (COGINE-#env), as well as the Central Nexus component. COGINEs A through F handle the traffic around the gate terminals. COGINE-WNear and COGINE-WFar handle ground traffic on the west side, near and away from the terminals. Likewise, COGINE-ENear and COGINE-EFar serve the airport’s east-side traffic. The coverage area is selected to reflect current-day and possible future expansion operations. For example, the duties of gate assignment are controlled by the airlines today, but in the future, that task may be relinquished to automation. COGINEs A-F may fill that role, playing the roles of gate pushback scheduler, or even ramp-side conflict detection. The COGINEs in figure I.2 collaborate to provide optimized advisories for arrivals and departures. The notional COGINEs can perform multiple functions (such as taxiing route planner, schedulers, planners, and conflict detection components) depending on their configuration.

In addition to the ten COGINEs supporting surface management, the other seven COGINEs in figure I.3 work to provide additional constraints, integration, and dispersion of information to all collaborating COGINEs. The tasks of the COGINE-#env’s are to examine environmental impact using modeling, determine limitations and restrictions of usage, and provide guidance to the optimization COGINEs. Coordination of the environmental COGINEs is the task of the airport environmental engine (COGINE-APenv; fig. I.3).

Overseeing all the COGINEs at the airport is the Central Nexus, with one deployed at each airport. The Central Nexus assembles all the strategic and tactical plans compiled at the airport (although an implementation time frame is not defined at this time) and can share these plans with external entities. In this setting, the Nexus can act as an information router-broker to other ATC systems, such as those deployed in the terminal and en route domains. Another duty of the Central Nexus is keeping all COGINEs informed of the working playbook and future configuration changes, which can modify and constrain many calculation parameters.

The example in figure I.3 shows three layers of command and control for the DFW airport employing the DISSEMINATE concept. At the top level is the Central Nexus, which communicates with the COGINE-APenv and all other non-environmental COGINEs. In this example, the environmental COGINEs (third layer) report to the airport’s overall environmental computation engine (COGINE-APenv). Depending on the airport’s layout and proximity to nearby residences, there may not be a need for the individual environmental COGINEs, which can be replaced with one COGINE-APenv that communicates directly with the Central Nexus. In figure I.3, the environmental COGINEs cover the area beyond the airport property, and can be made to represent and capture the noise footprint in the surrounding neighborhoods.

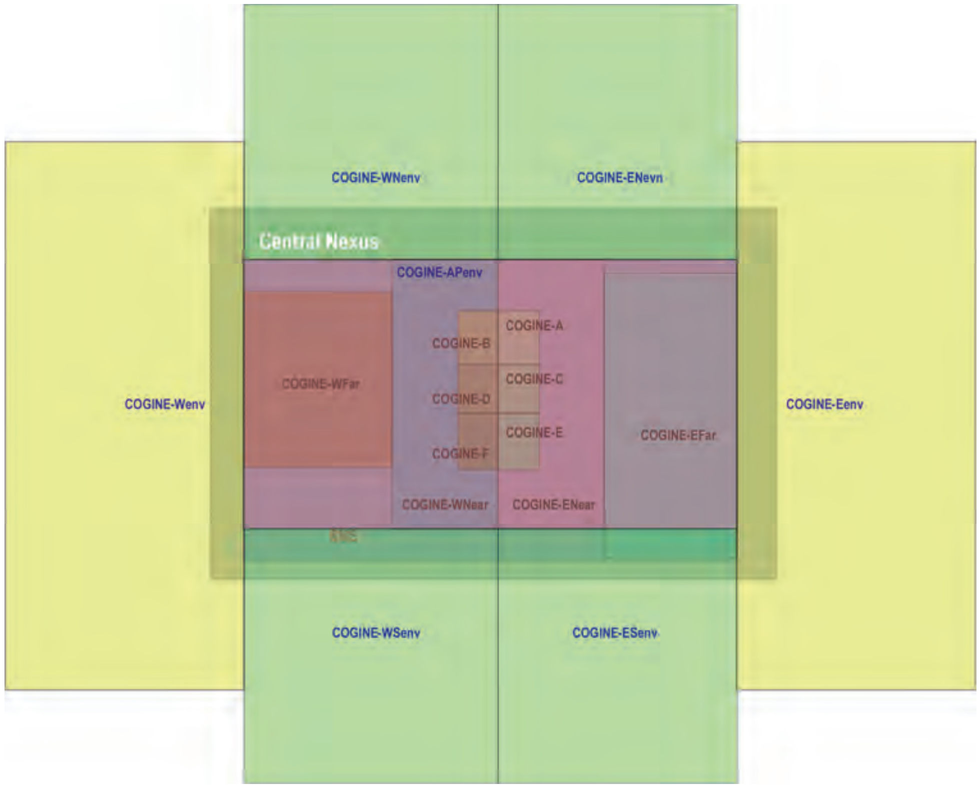


Figure I.3: The conceptual deployment of 17 computational engines (COGINEs) by DISSEMINATE for producing optimized traffic movement at the DFW airport.

DISSEMINATE presents a distributed framework that can be used to address the complex surface optimization problem. There are many ways to implement this framework, and it is not the intent of the author to specify an implementation method. In one deployment scenario, the framework can be viewed as running 18 instances of SMS, albeit with data-sharing capability that does not currently exists. The other extreme solution may involve a single SMS that can provide the desired solution, given enough computational power. For the remainder of this white paper, the author has elected to use a hybrid model, which fits somewhere between the two extremes.

The hybrid model uses the core SMS capability (database management, flight plan processing, estimated time of arrival (ETA) calculation, communications, etc.) along with to-be-developed COGINEs. The model employs one SMS using distributed COGINEs to devise a solution. In this manner, the SMS functions as the Central Nexus of the hybrid system. A comparison of three architectural designs is shown in table I.1. It assumes the use of the SMS version with the plug-in module capability (version 8.2). The plug-in modules will play a pivotal role in the development of COGINEs (essentially extending the plug-in module with more data-sharing capability between modules and the Central Nexus to become a COGINE).

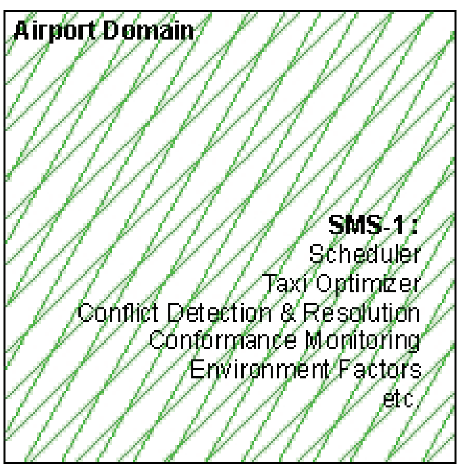
Notionally, start by using the SMS as a seminal engine for DISSEMINATE (table I.1, Option A). Option A behaves like the current-day SMS system, with one instance providing coverage over the entire airport. Option B denotes four SMS instantiations that provide coverage over the same airport domain. In this example, the SMS will need an added feature to promote the data sharing between the systems.

One SMS will become the Central Nexus or hub to coordinate the other systems. Next, the primary usage of each SMS is identified. Its functionality is ascertained; is it to behave primarily as a scheduler, optimizer, conflict detection and resolution alert mechanism, conformance monitor, or an environmental impact calculator. There might be other roles that it can assume.

Option C shows the transformation of Option B into a DISSEMINATE system by transforming one SMS into a Central Nexus (functionally), while distilling the functions of the other three SMS systems into multiple COGINEs. For example, once identified, the primary and secondary utility of each SMS (non Central Nexus) is distilled into core functionality. Next, ancillary and nonessential components are stripped away from the SMS. In essence, the distilled SMS represents the computational engine or COGINE in the DISSEMINATE framework. The main SMS (which becomes the Central Nexus) resumes coordination role over the COGINEs. Alas, each COGINE will be configured to govern a subset of the airport domain. In this distributed network, each COGINE strives to solve local problems while keeping situational awareness by exchanging data with adjacent COGINEs and the Central Nexus (table I.1, Option C).

The author has selected the hybrid model because it exploits current architectural improvements in SMS. More specifically, the plug-in architecture provides the key technology to transforming SMS into a distributed system. The functionality of the plug-in module defines the characteristic of the COGINE.

Table I.1: Illustration of Three Architectural Design Options

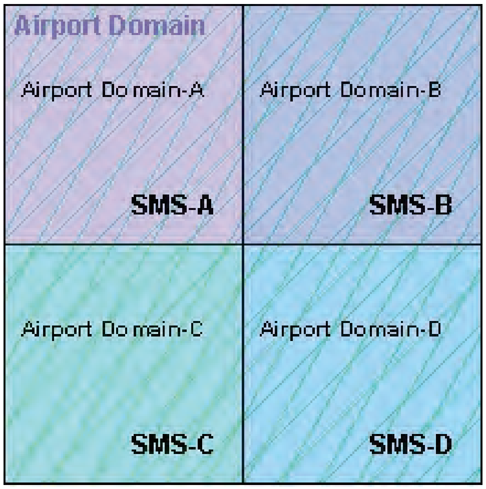


Option A: Centralized Architecture

Option A: Centralized Architecture

This centralized architecture uses one instance of SMS (SMS-1) to provide flow control over the entire Airport Domain. It is hypothesized that this approach will get bogged down as more and more constraining parameters are levied upon the system. The system footprint is small, requiring just one SMS deployment. A short list of features is shown for the SMS-1 model.

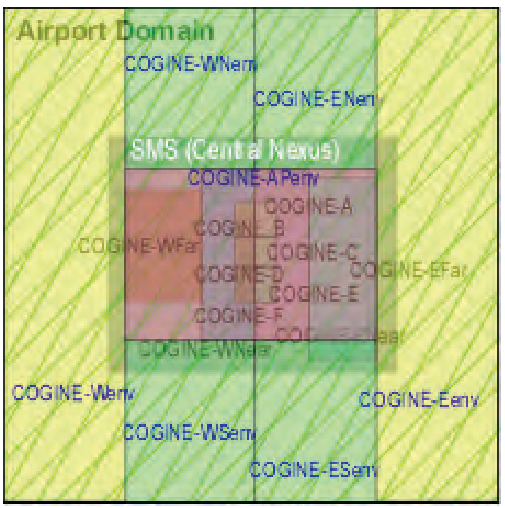
Note: The green hash marks denote the same airport domain that all three models provide coverage over.



Option B: Distributed Architecture

Option B: Distributed Architecture

The distributed approach breaks down the Airport Domain problem into four sectors, with each system solving a smaller area. Four independent systems (SMS-A through D) are deployed to solve the problem. Software development is required to promote data sharing between the four systems. Some changes to the adaptation data may be required to accommodate the SMS with the subsector layout. One major drawback of this design is the deployment of four complete instances of SMS. Functionality is similar to the SMS-1 model in Option A.



Option C: Hybrid Architecture

Option C: Hybrid Architecture

The hybrid approach uses the best features of the centralized and distributed systems. The hybrid system uses a single deployment of SMS, albeit with modifications to accept multiple instances of similar-type plug-in modules. The modules and the associated airspace are coupled to form the COGINE over the particular region. The diagram shown is similar to figure I.3. Software modification to the current SMS is required for it to interface with multiple COGINEs and the Central Nexus. The hardware requirement falls between Options A and B, but it is expected to have the performance level of Option B and additional flexibility for future expansion.

2.4 The Computational Engine (COGINE)

2.4.1 COGINE Architecture

The components illustrated in figures I.1 through I.3 are discussed in detail in this section. Option C, the hybrid model, is used as the example model for this section as well. The SMS modular plug-in framework contributes the key feature of the distributed network. Figure I.4 shows the plug-in modules identified for the redesign of the SMS.

COGINE represents the logical grouping of computational modules represented in figure I.4, for example. Their combination is selected to solve the problem relevant to the construct of the COGINE and the physical domain it controls. Figure I.5 shows a sample COGINE and a typical selection of modules. Combining the computational modules in figure I.4 with the selection of the COGINEs defined in figure I.3 results in the depiction of figure I.6.

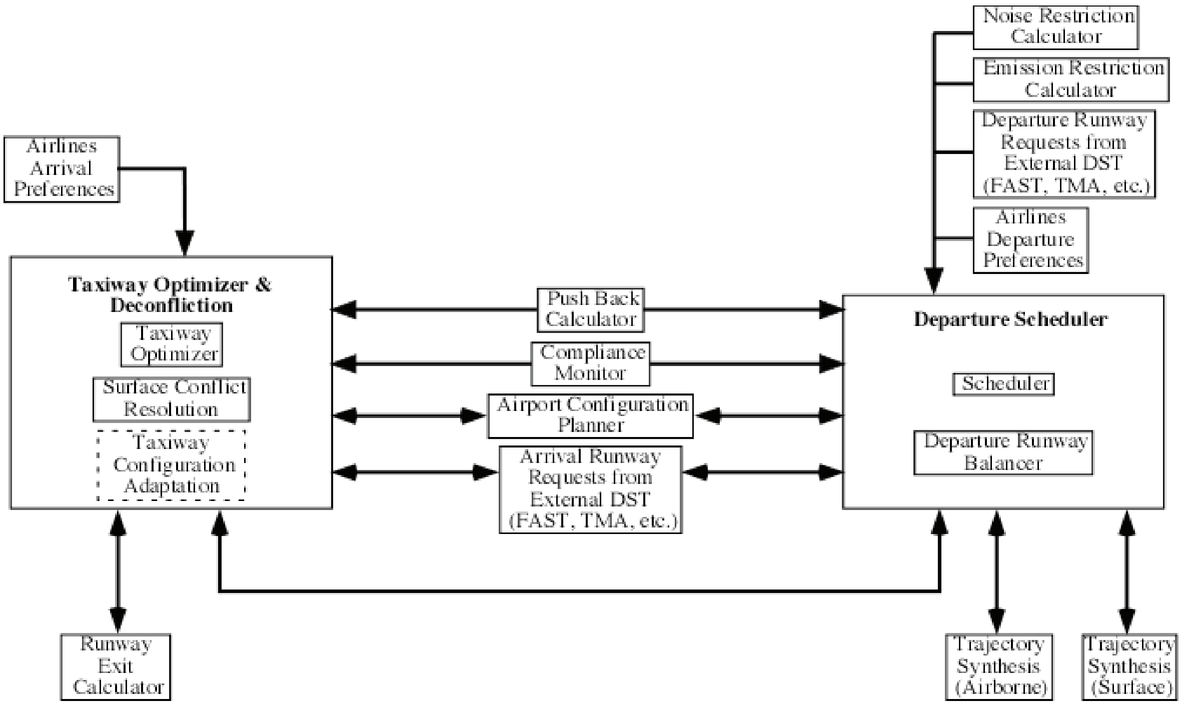


Figure I.4: SMS plug-in modules.

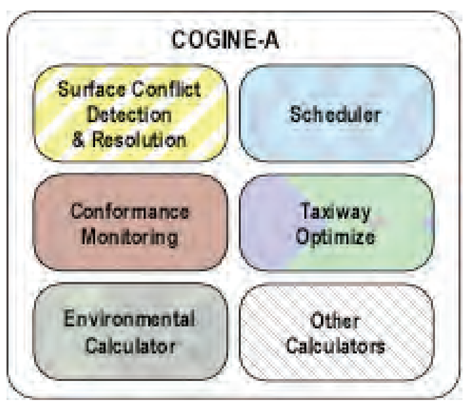


Figure I.5: Sample COGINE with constituent modules.

The example in figure I.5 shows five computational components with the sixth signifying a miscellaneous category for inclusion of emerging technologies. COGINE components are synonymous to the plug-in modules of SMS. Functionally and architecturally, they represent the same entity. The general concept depicts the flexibility and purposeful implementation of the COGINEs. The components are not unique to any particular COGINE but are, in fact, designed for generic application. As such, the COGINE employs appropriate components and the necessary instantiations to converge upon a solution.

Besides being able to use multiple instantiations of the same module, the COGINE may call variations of similarly developed components. For example under the Taxi Optimizer type, there may exist a first-come, first-served (FCFS), mixed-integer linear programming, and a heuristic model. Each model has its own strengths and weaknesses, and the COGINE intends to leverage the strengths of each model as the condition arises. The combination of using multiple instances and application of similarly typed components offers much flexibility for the COGINE. As various plug-ins or components get developed for SMS, they will become available to the COGINE too.

The COGINE's selection of components defines the unique role of its functionality. Selection and priorities can be assigned to each component. For example in figure I.6, the environmental COGINE (say COGINE-WNenv) de-emphasizes (semitransparent/grayed out) the conflict detection, scheduler, conformance monitoring, and the taxi optimizer components. The situation is different for COGINEs providing support near the terminal areas (COGINE-A through -F) and runways (COGINE-xFar and -xNear). The COGINEs, Central Nexus, and conceptual data-sharing scheme (publish-subscribe) are presented in figure I.6.

Figure I.7 depicts a data exchange framework within the COGINE, which is very similar to the DISSEMINATE layout in figure I.6. Similar to the Central Nexus, each COGINE will have a COGINE Nexus (CoNex) to provide coordination of intra- and inter-COGINE communications. The CoNex can operate as gateways to other CoNexes (COGINEs) as well as the Central Nexus. The framework allows decoupling of the design of the COGINE to that of the Central Nexus. However, the communication mechanism is very applicable for both model layers.

The intent again is to provide flexibility for intra-COGINE as well as inter-COGINE connectivity. The DISSEMINATE model in figure I.6 uses a sample publish-subscribe mechanism to promote inter-COGINE communication. The publish-subscribe model was chosen for McTMA because of its flexibility to connect a multiple metering-complex, which is similar in concept to the COGINE.

As alluded to in table I.1, Option C, the selection and creation of the COGINE requires a balance between art and engineering. Many factors can affect the forging of the engine, such as primary and secondary functions, computational ability, geographical layout, logical layout, and ATC ownership jurisdiction, just to name a few. Figure I.7 highlights the importance of including the appropriate adaptation data set needed to define each COGINE. Along with the computational components, the adaptation set defines the domain of control. Figure I.2 and I.3 show the creation of COGINE with consideration to geographical, logical, and ATC jurisdiction factors.

2.4.2 Central Nexus and COGINE Nexus (CoNex)

Conceptually, the COGINE framework allows for flexibility and robustness because each COGINE is designed to work independently of one other. This allows for some clever implementations of the COGINEs, but it does demand some coordination and control over multiple COGINEs. Potential problems arise when COGINEs' output conflict with one another (either with value or timing of data). Because of possible conflicting information and messaging, the Central Nexus needs to keep accurate account of all COGINEs (via its CoNex) and their functional characteristics.

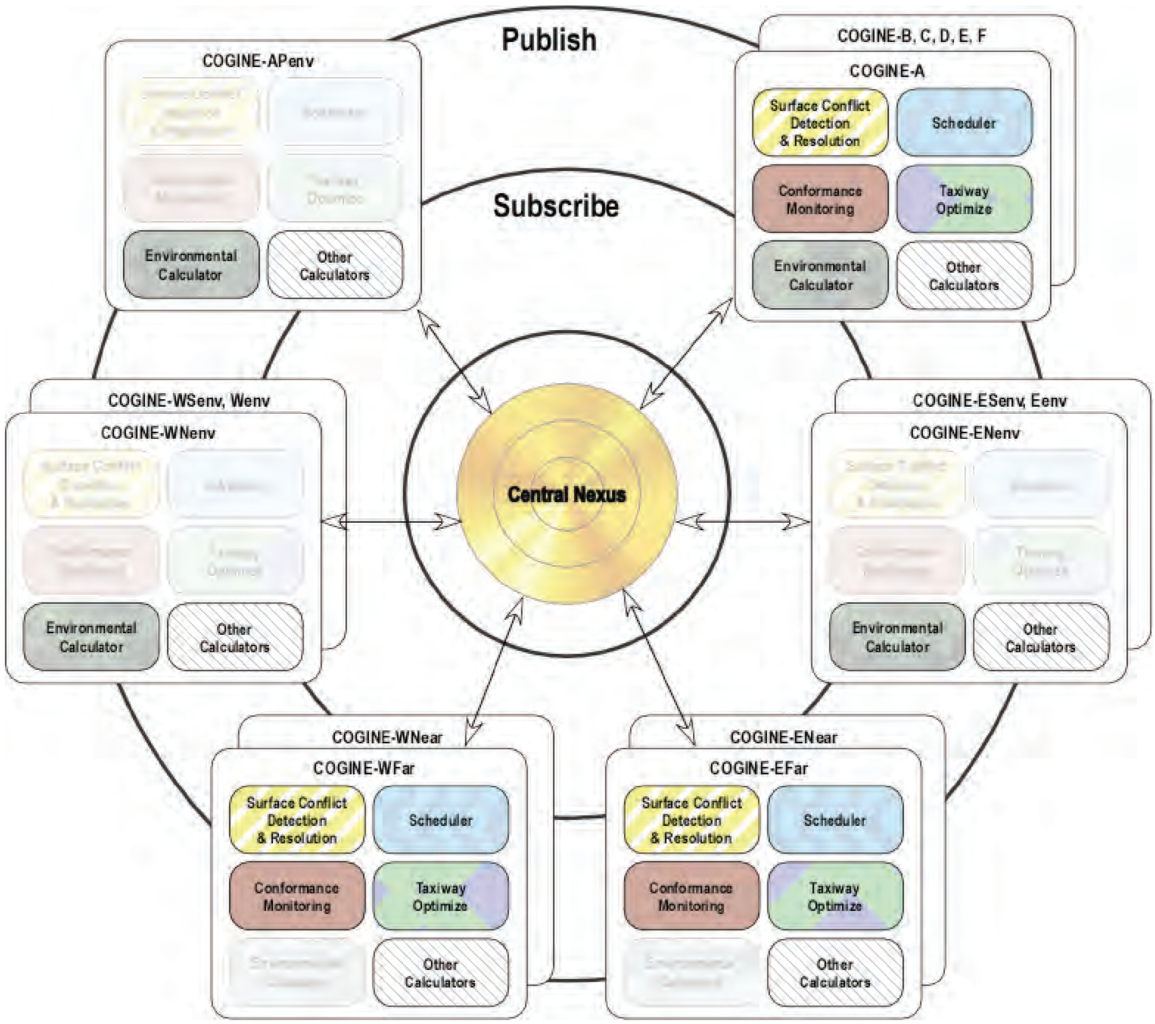


Figure I.6: DISSEMINATE using the hybrid architecture with COGINEs and two data sharing techniques, direct connection and peer-to-peer connection (publish-subscribe).

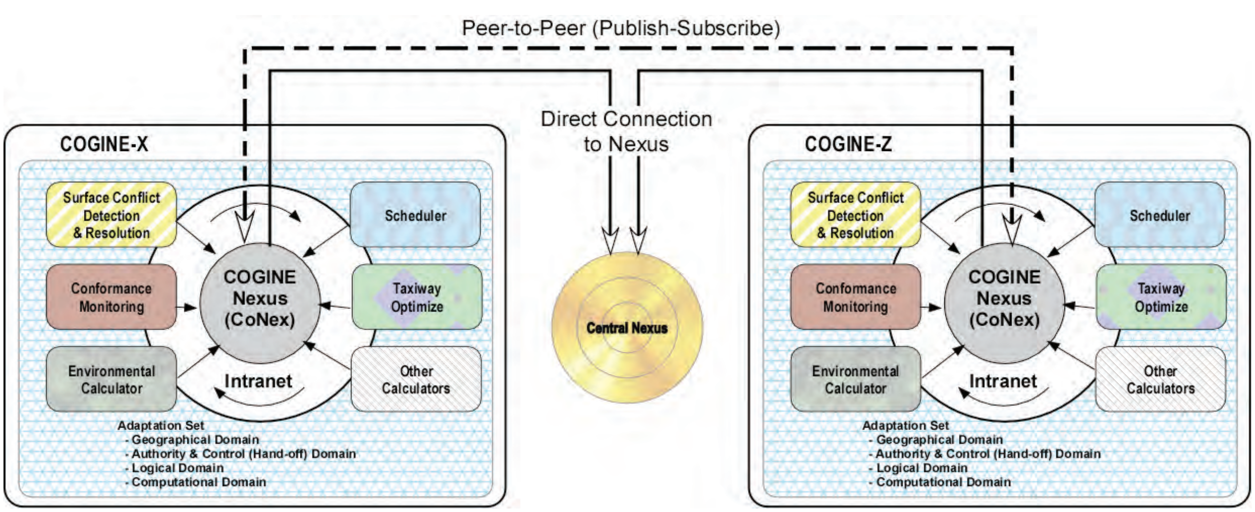


Figure I.7: Communication model between Central Nexus and COGINE Nexus (CoNex).

The Central Nexus is designed to perform multiple functions. It acts as a gateway between the intranet and Internet, relays and routes data between CoNexes, imposes communication protocols standards between COGINEs, maintains a master database of traffic, and provides data logging. The last two items, database maintenance and data logging, currently exists within SMS; the other features are new. Figure I.8 illustrates the connectivity options of the Central Nexus.

The diagram shows both intranet and Internet clients. In the Internet example, other Central Nexus may represent a Metroplex environment, and connectivity with other DST can represent interaction with the Traffic Management Advisor (TMA), Traffic Flow Management, or Separation Assurance tools. Of note, the term Internet is used to represent the extended network beyond that of the Central Nexus' network, for an operational system; it may connect to the FAA's secured System Wide Information Management (SWIM) network.

The Central Nexus may aid collaboration between COGINEs by defining collaborative protocols, setting common planning and controlling horizons, and activating and deactivating COGINE signals due to change in operational conditions.

For example, the Central Nexus may need to set a control horizon that may be different from the working horizons implemented by each COGINE. Suppose the scheduler in COGINE-X works on a 90-minute horizon and another scheduler in COGINE-K works on a 60-minute horizon. The Central Nexus may need to set a working horizon of 45 minutes, which may force the COGINEs to publish only traffic within the 45 minutes. Yet, the COGINEs are free to work within their desired horizon settings.

Functionally, the CoNex behaves very much like the Central Nexus. Its purpose is to route data and set operational protocols between the computational modules, just like the Central Nexus. What CoNex lacks are higher level features like formulation of the larger picture based on data from adjacent DSTs and Central Nexus. From a simplistic view, the software framework developed for the Central Nexus can be trimmed down to become a CoNex.

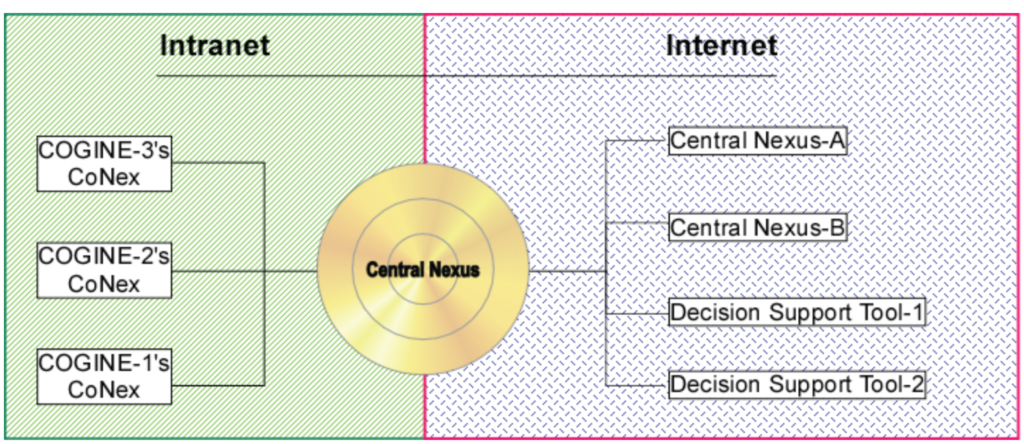


Figure I.8: Central Nexus interfaces between intranet and Internet clients.

3. POSSIBLE APPLICATIONS OF DISSEMINATE

The flexible and robust assemblage of building blocks offers many ways to formulate an approach to address a problem. This section offers sample applications of the DISSEMINATE framework with judicious use of COGINEs. The examples include settings for flexible sectorization, modeling of Metroplex airspace, and machine-human transfer modes. These are some of the perceived benefits that such a flexible model can offer.

3.1 Sectorization Options

As stated in the prior section, the COGINE framework can provide different ways to assemble calculation components to implement a solution. Designing the COGINEs requires a balance between art and science. The COGINEs in figure I.3 are placed abutting each other in plan view. However, one can extrude the two-dimensional (2-D) area into a three-dimensional (3-D) volume, such that the COGINE can include an altitude parameter, as illustrated in the side view shown in figure I.9. From this perspective, the COGINE can represent a typical airspace sector. This bodes well for the environmental COGINEs, which model the airspace further out and may include the descent and climb phases of flight.

Using a 3-D model, one can design a stratified sector to build appropriate COGINEs to control traffic. One possible use for this configuration is sectorization, the combining and de-combining of sectors to manage demand and workload, reflecting changing traffic levels. Figure I.9 depicts COGINE-T controlling the airspace above COGINEs L and R. On the surface, having an altitude component doesn't make much sense. Instead, think of COGINE-T as an overlay over the other two components that can supplement or supersede the tasks of COGINEs L and R during low-traffic hours.

All COGINEs can be configured in advance and invoked when the situation demands it. The switch over between different COGINEs can be configured through the Central Nexus. In less congested times, the Central Nexus can idle COGINEs L and R, and route similar decision-making activities to COGINE-T and vice-versa if necessary. This framework can conceivably support dynamic activation of COGINEs, which requires preconfigured setups and coordination between the CoNex and Central Nexus. The inactive COGINEs can be left inactive or shut down completely to recoup needed resources.

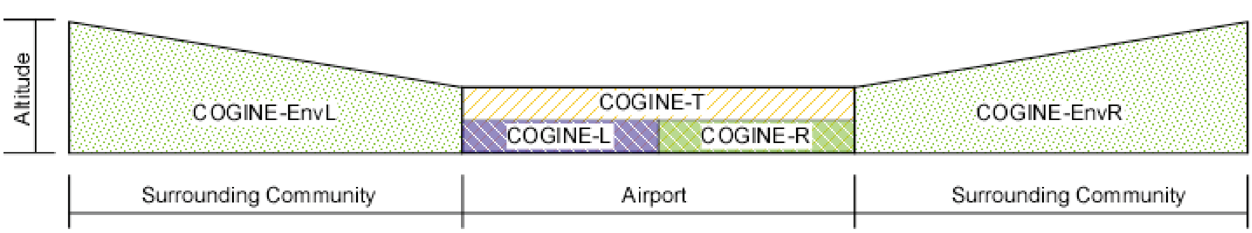


Figure I.9: Side profile of a stratified COGINE configuration.

Similar stratification modeling can be made to the environmental COGINE-Env#s as well. The size of the environmental COGINE can shrink and grow, or additional COGINEs can be added depending on time of day and season. The flexible sectorization capability may be too complicated for the operator to handle, so automation may be necessary to advise the user of when to take advantage of this capability.

In another scenario, COGINEs L, R, and T can all be active. In this case, COGINE-T can function as a conformance monitoring system or even a conflict detection and resolution unit. Thus, COGINE-T is providing additional coverage for COGINEs L and R, or it can be configured to behave as an engine that uses coarser fidelity but with a farther-out prediction horizon.

3.2 Metroplex Modeling

The modular architecture can offer an approach to model the Metroplex airspace. Two example applications of the DISSEMINATE framework are presented in the figures below. Figure I.10 shows the deployment of three DISSEMINATE systems, representing the Bay Area Metroplex with the San Francisco (SFO), Oakland (OAK), and San Jose (SJC) airports. The three systems exchange data via their representative Central Nexus.

Figure I.11 uses a single Nexus to coordinate with the CoNexes of each respective airport. The figure depicts a larger Central Nexus size than the one in figure I.10, to signify the larger role it plays in coordinating with the CoNexes. Each airport is expected to deploy similar, but differently configured, COGINEs and is depicted using different color patterns. The strengths and weaknesses of each design have not been scrutinize at this time, although at first look, figure I.10 may offer more autonomy and robustness due to the use of three independent Central Nexuses. Figure I.11 may have a single point of failure, but may offer more collaboration between parties. Besides, having redundancy may offset the single point of failure choke point.

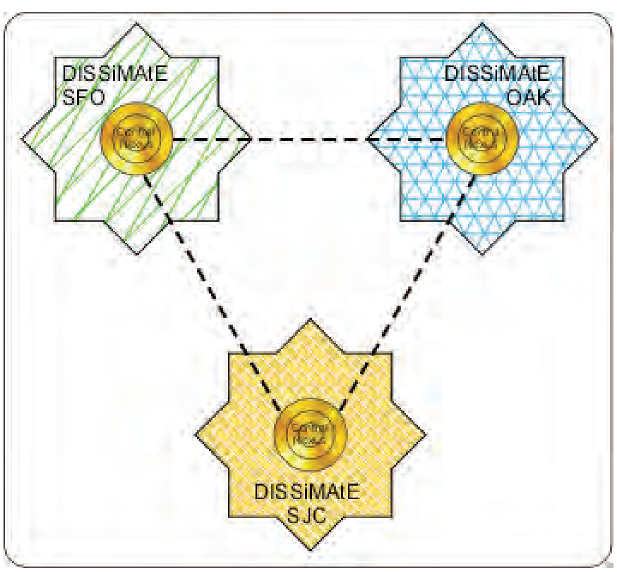


Figure I.10: Configuring Bay Area Metroplex using three DISSEMINATE systems, one each for SFO, OAK, and SJC.

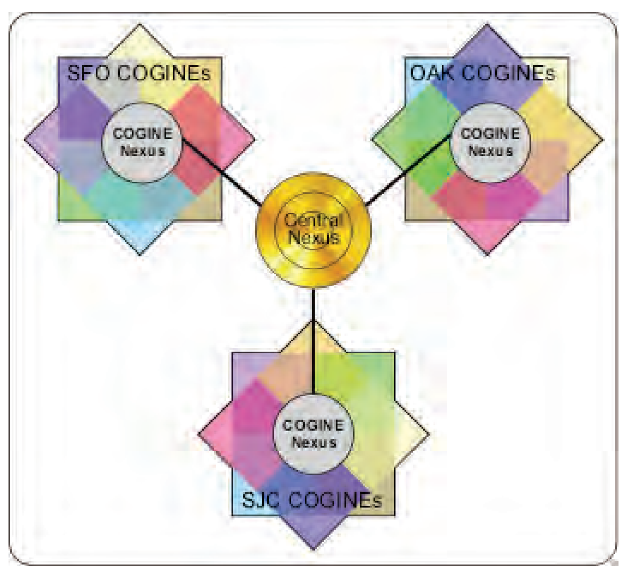


Figure I.11: Configuring Bay Area Metroplex using one DISSEMINATE system with localized COGINEs at each airport.

3.3 Automation-Human Handoff, Mitigation Plan, and Migration Training

Machine-human control migration mode refers to the transfer of control from decision support tool (DST) or automation back to the human operator. The operational assumption is that in the mid- to far-term time frame, automation deployment will be more widespread than it is today. Automation has made its way into daily operational use and is conducting the majority of the air traffic management. But for any number of reasons, the human operator may need to intervene and resume some of the tasks from the automation. DISSEMINATE may offer some assistance with the transition process and provide a possible mitigation plan to ensure a successful transition. The scenario becomes more important in the NextGen time frame when traffic is expected to double.

DSTs are being built to be more efficient in handling the increased traffic. A major shortcoming of such an efficient and automated system occurs when something goes awry and requires human intervention. Regardless of the source, the end result may require placing the human operator back into the control loop. Many research groups have identified this point as an area of concern and one that needs further study. A major disturbance on the surface in a highly congested but efficient system can ripple many hundreds of miles upstream and downstream of the airport.

In short, the migration plan involves systematic substitution of the human controller into the control loop. The systematic migration of control may be more feasible with a distributed system such as DISSEMINATE than with a monolithic system. Figure I.12 illustrates an example where COGINE-C and COGINE-EFar are being replaced with human controllers. System inefficiency will be felt during the transition period, but it is expected to be less impactful then bringing the entire system down and substituting all DST controls with human controllers, because the remaining COGINEs can still operate within the new situation but in the degraded mode.

The concept involves placing more restrictions upon adjacent COGINEs to give the human operator a chance to assess the situation, and develop and implement a control plan. The traffic management unit (TMU) or equivalent will make systemic requirement changes while the controller works to clear out the sector congestion. Referring to figure I.12, say Controller-C takes the place of COGINE-C. Throughput to and from Controller-C will be reduced. This will impact the handoffs between Controller-C with COGINE-A, COGINE-E, COGINE-ENear, and possibly COGINE-D. In turn, the TMC may restrict flows from COGINE-WNear and COGINE-EFar to Controller-C. In addition, COGINE-EFar is also being replaced with Controller-EFar. Thus COGINE-ENear may take on additional constraints from Controller-C and Controller-EFar.

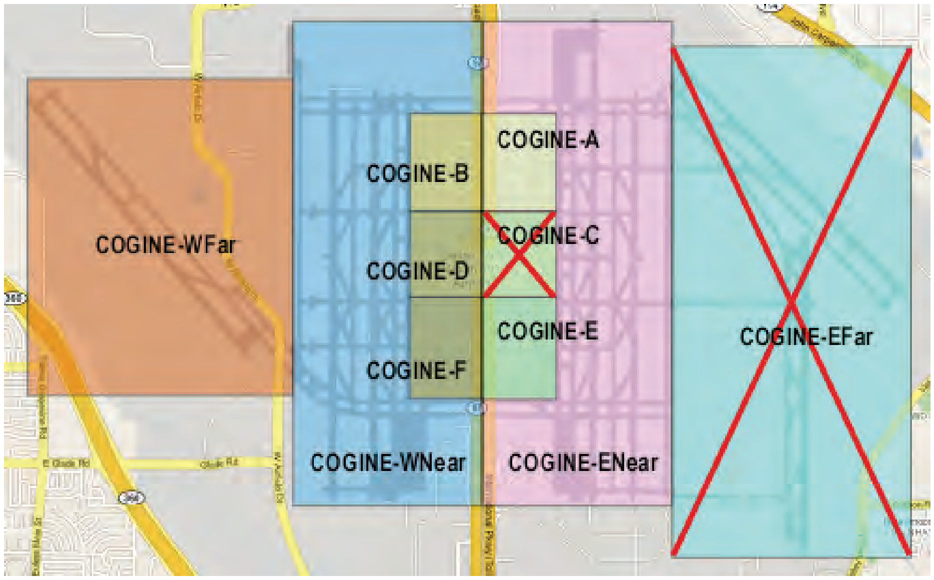


Figure I.12: Two COGINEs are systematically replaced with human controllers.

Training can help controllers be proficient in making the transition. DISSEMINATE can also help with the training process. During low-traffic periods, selected COGINEs can be deactivated so the human controller can take command. Again, more restriction will be imposed on adjacent COGINEs to protect the operator, but this should not be an issue during off-peak periods. Ideally, a DISSEMINATE simulator can be set up to run in a simulated environment where training can occur with more intensity. The simulator can aid both controllers and traffic management coordinators by designing and selecting COGINE activations.

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